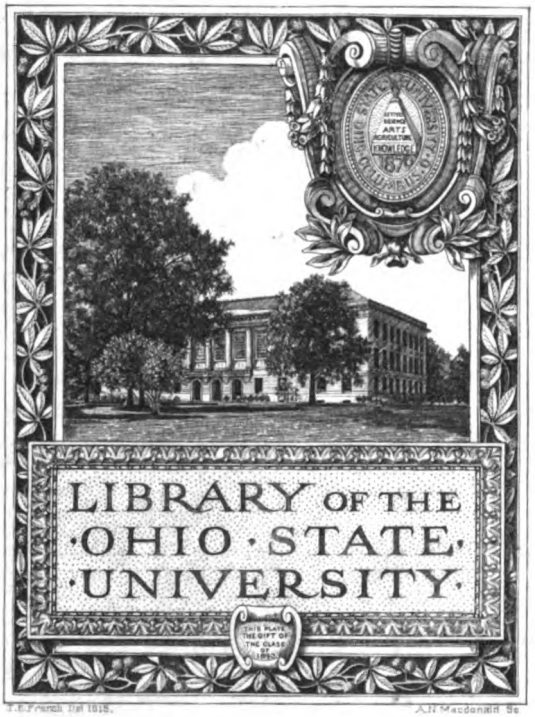
ANNALS OF ROENTGENOLOGY · VOL · IV
EDITED BY JAMES T. CASE, M.D.

NORMAL BONES & JOINTS

ISIDORE COHN, M.D.

Foreword by RUDOLPH MATAS, M.D.

Digitized by Google



Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

NORMAL
BONES AND JOINTS

ANNALS OF ROENTGENOLOGY

VOLUME FOUR

Digitized by Google

ANNALS OF ROENTGENOLOGY

A SERIES OF MONOGRAPHIC ATLASES

EDITED BY JAMES T. CASE, M.D.

Ex-President of The American Roentgen Ray Society

Volumes Published:

I. MASTOIDS—By FREDERICK M. LAW, M.D., New York

II. THE PATHOLOGICAL GALL-BLADDER—
By ARIAL W. GEORGE, M.D., and RALPH D. LEONARD, M.D., Boston

III. DIGESTIVE DISTURBANCES IN INFANTS AND CHILDREN—
By CHARLES G. KERLEY, M.D., and LEON T. LEWALD, M.D., New York

IV. NORMAL BONES AND JOINTS—
By ISIDORE COHN, M.D., New Orleans

Volumes in Preparation:

V. THE TEETH AND JAWS—By HERMAN A. OSGOOD, M.D., Boston

VI. SKULL FRACTURES—By WILLIAM H. STEWART, M.D., New York

VII. DIVERTICULA OF THE ALIMENTARY TRACT—
By JAMES T. CASE, M.D., Battle Creek

VIII. NASAL ACCESSORY SINUSES—By FREDERICK M. LAW, M.D., N. Y.

IX. THE URINARY TRACT—
By HUGH H. YOUNG, M.D., and CHARLES A. WATERS, M.D., Baltimore

X. THE CHEST—
By JAMES T. CASE, M.D., and J. STUART PRITCHARD, M.D., Battle Creek

Order of Publication and volume numbers subject to change
Other volumes to be announced

PAUL B. HOEBER, INC., *Publishers*

67-69 EAST 59TH STREET NEW YORK CITY

Digitized by Google

ANNALS OF ROENTGENOLOGY

A SERIES OF MONOGRAPHIC ATLASES

EDITED BY JAMES T. CASE, M.D.

Ex-President of THE AMERICAN ROENTGEN RAY SOCIETY

VOLUME FOUR

NORMAL BONES AND JOINTS

ROENTGENOLOGICALLY CONSIDERED BY

ISIDORE COHN, M.D., F.A.C.S.

WITH A FOREWORD

BY RUDOLPH MATAS, M.D.

PAUL B. HOEBER, INC.

67-69 EAST FIFTY-NINTH STREET

NEW YORK

Digitized by Google

Digitized by Google

ANNALS OF ROENTGENOLOGY · VOLUME FOUR

NORMAL BONES & JOINTS

ROENTGENOLOGICALLY CONSIDERED

TWO HUNDRED AND TWENTY ROENTGEN RAY STUDIES
ON SIXTY-ONE FULL PAGE PLATES AND
THIRTY-FOUR TEXT ILLUSTRATIONS

BY

ISIDORE COHN, M.D., F.A.C.S.

Professor of Clinical Surgery, Tulane University, Associate Senior Surgeon, Touro Infirmary, New Orleans, La.

WITH A FOREWORD

By RUDOLPH MATAS, M.D.

Professor of General and Clinical Surgery,
Tulane University, New Orleans, La.

NEW YORK

PAUL B. HOEBER, Inc.

MCMXXIV

Digitized by Google

COPYRIGHT, 1924
BY PAUL B. HOEBER, INC.

PUBLISHED SEPTEMBER, 1924
All Rights Reserved

STATE OHIO
UNIVERSITY

Printed in the United States of America

Digitized by Google

THIS VOLUME IS DEDICATED TO

DR. RUDOLPH MATAS

MY FRIEND, TEACHER

AND DISTINGUISHED

ASSOCIATE

290412

Digitized by Google

Digitized by Google

EDITOR'S PREFACE

IT is too much to expect that any man can be a specialist in all of the branches of medicine in which roentgenology plays a useful part. True, one finds here and there an exception who, because of a specially fortunate series of events and an unusually large clinical experience, is endowed with great usefulness as a roentgenologist with a broad viewpoint; but the average physician working with the roentgen rays, even if he restricts his practice to the use of this newer diagnostic and therapeutic arm, feels keenly his lack of training and experience in many of the branches of medicine in which his roentgenologic aid is sought. Again and again in the presence of a case in one of the less familiar lines, he will find himself longing to make comparison with roentgenograms of some proven case of a similar nature, wondering what roentgenologic pitfalls he must avoid. He may recall having seen some similar case in a postgraduate course but his memory of the plate details is too hazy for reliance.

The scope of the roentgenologist's judgment is measured by the experience he can fall back upon. It is to supply a diagnostic guide rich in the fruit of experience of leading authorities in special fields of *x*-ray that the Editor and the Publisher have conceived the production of this series of monographic atlases, to bring to the roentgenologist at home a postgraduate course from the very men whom he would seek in personal visit, and to leave with him an invaluable series of master roentgenograms which he may study and with which he may make comparisons as often as desired.

In presenting this fourth volume of the Annals, the editor and the publishers feel that an explanation is due for the omission of the Spanish

Digitized by Google

and French translations. In the past these translations have been undertaken only of the captions underneath the illustrations in the text and in the explanations of the plates. In this volume the nature of the text in relation to the illustrations is such that any translation made would have to be a complete translation of the text of the book. This, it is felt, would increase not only the bulk of the work, but also the price, out of all proportion to the value of the translations. Furthermore, the rendition of a considerable part of the reading matter into foreign languages has been considered as detracting from the value of the text, and many of the English readers have inferred that they have, in the end, been paying for the Spanish and French translations. Our present plan, therefore, is to discontinue the French and Spanish translations in future volumes of the Annals.

JAMES T. CASE.

BATTLE CREEK, MICHIGAN.

Digitized by Google

PREFACE

I cannot submit this volume for publication without expressing my debt of gratitude to those who have encouraged my efforts, and to those who have assisted with the work.

I wish particularly to mention my friend, Dr. J. Shelton Horsley, of Richmond, Virginia, who suggested the publication of this work in book form.

I wish also to acknolwedge gratefully the splendid cooperation of the Superintendent and Board of Managers of Touro Infirmary, in allowing the research work to be done in the *X*-ray Department of the institution. Special thanks are due Drs. Samuel and Bowie, of the *X*-ray Department, and Mr. Goodman, the technician, whose unfailing kindness will never be forgotten. To my associates, Drs. Lacroix and Gage, I wish to make acknowledgment for help rendered in preparing parts of this work.

I also wish to acknowledge the courtesy of the publishers for their cooperation.

Grateful acknowledgment is made to the Archives of Surgery and The American Journal of Roentgenology for the privilege of including in this volume illustrations which appeared in those journals.

It is hoped that our critics will look upon this as an effort to clear up some of the mooted points about the appearance of joints at various ages.

ISIDORE COHN.

1522 ALINE STREET,
NEW ORLEANS, LA.
August, 1924.

Digitized by Google

Digitized by Google

FOREWORD

The recent death of Wilhelm Konrad Roentgen on February 10, 1923, has roused the scientific, especially the medical, world, to a sense of the immense debt that it owes to his genius. Some of his biographers and others interested in recording the progress of science have attempted to survey the vast domain that he first discovered and explored. The German Roentgenological Society in 1914, compiled a catalogue of 15,000 titles embracing the roentgenological literature that had appeared up to that time, and yet this index was incomplete as it registered only contributions that pertained strictly to roentgenology. Of a large number of clinical and other professional as well as nonprofessional papers in which roentgen rays were indirectly concerned, this index took no account. Bibliographic compilations of this character may afford some estimate of the gigantic volume of literature which has sprung up as if by magic from the seed sown at Würzburg a little over a quarter of a century ago (December 28, 1895). But no bibliographic index, no matter how voluminous, can exhibit in its fullest light the incalculable influence that Roentgen's portentous discovery has exercised upon the progress of the pure, as well as the applied, sciences, of which the healing science and art have had the most direct and immediate benefit. Roentgen's demonstration of the penetrating powers of the *x*-rays startled the world with its immense practical possibilities and the application of the new light to the problems of medicine and allied biologic sciences obscured and overshadowed the effect that its interpretation has had upon the progress of the physical and chemical sciences as an initial step in the historical evolution of radioactivity and as the foundation of the new science of radiology.

Roentgen rays, through the mystery that surrounded their origin and mode of production, spurred the finest brains of the century to new efforts and to marvelous accomplishments. These, following in rapid succession,

Digitized by Google

have built a new foundation in speculative philosophy which has culminated in a radical reconstruction of the older concepts of the atom, and, in this way, illuminated the very essence of primordial matter itself.

Roentgen himself knew and foretold that great events and developments would follow in the wake of his discovery, but neither he nor the most inspired prophet of his time could dream of the amazing realities that greeted his eyes long before his death. He knew that technical improvement must precede all progress. But he did not realize that the primitive apparatus which he adapted to his purpose would be so perfected that in a few years a roentgenogram could be obtained of any part of the body, with almost microscopic detail, by an exposure of $\frac{1}{200}$ of a second and less, while it formerly took over thirty minutes to obtain one of the hand. Of the distant possibility of "ortho," "tele," "stereo" and "cinema" radiography, he might, as a physicist, have conceived; but of the visualization of the alimentary and other hollow tracts, of pyelography by the use of opaque substances, of radio-pneumoperitoneum, of ventriculography, etc., he could scarcely suspect; and much less did he dream of the biologic effect of the *x*-rays on cell growth and cell destruction, upon which has grown the latest, most ambitious and outstanding offshoot of the therapeutic branch of the roentgenologic tree,—*deep* radiotherapy.

Surgery, as the most objective branch of medicine, was the first beneficiary of Roentgen's discovery and, in surgery, the osseous framework lent itself most readily to the new mode of physical exploration. It was with the first roentgenogram of the bones of his own hand that Roentgen demonstrated to the astonished world that "the dream of ages had been fulfilled, that the human eye could penetrate and see into the deepest depth of the tissues." At first only the most accessible bones of the extreme periphery, hand and foot, were exposed, in their nakedness, to the new light. Then, proceeding from periphery to center:, the arm and shoulder, the leg, the

Digitized by Google

thigh and the hip, the pelvis, the spine, the thorax and lastly, the cranium, yielded their secrets to the magic lamp of this real Aladdin. Only to those who have lived through the transition period and have followed in the rugged trail of the pioneers of the "nineties," is it given to recall the early difficulties experienced in attempting to visualize the details of the hip and shoulder with the technical resources then at our command. And it is also by recalling the risks and disasters that were incurred by the empiric application of the rays, or by contrasting the controlled effects of the 10-inch coil with the 20-inch modern transformer, that we can realize, in all its vividness, the enormous distance that we have traversed since that time.

It is apparent from these general statements that any attempt to sketch, even in its barest outlines, the vast scope of the roentgen discovery as applied to medical and surgical practice alone, would lead to an interminable rehearsal of well-known facts and generalizations which would be out of place in this discussion.

But even dealing with so limited and distinctly specialized a phase of surgical practice as the study of fractures and epiphyseal diastases of the extremities in their relation to the developmental anatomy of the skeleton (which is the subject considered in this volume), the recent death of Roentgen suggests thoughts which emphasize the profound influence of his discovery on the progress of surgery.

As to fractures, and for that matter, the whole traumatology and pathology of the osseous system, we know that they have become obligate tributaries to the *x*-rays. The vital problem of diagnosis is at present seemingly reduced to a mere matter of adequate transillumination. The enormous expenditure of hospital clinics for *x*-ray films alone, attests to the fact that an *x*-ray outfit has become a *sine qua non* in surgical practice. The illustrative quality and seeming finality of the roentgenogram in the diagnosis and treatment of fractures has appealed not only to the profession, but to the

Digitized by Google

popular mind, as is evidenced in the exaggerated importance often attached to the testimony of the *x*-rays in medicolegal controversies.

Through the combined influence of the roentgen light and the unparalleled opportunities of the Great War for the display of its supreme utility and precision in the diagnosis and treatment of fractures, the interest which had already developed in the treatment of these injuries before the war, was now intensified to a degree that amounted to a veritable renaissance of this important department of surgery. The awakened attitude of the surgeon to fractures at the present time is reflected in many ways: the introduction of new mechanical and surgical methods of treatment; the great volume of fracture and bone literature which has appeared since the war; the collective and comparative study of a great mass of statistical material by the leading surgical societies; the realization of the economic importance of fractures in their bearing upon the insurance aspect of the labor compensation problem, and the budgets of the great metropolitan hospitals. In consequence, the diagnosis and treatment of fractures is rapidly becoming a highly specialized branch of surgery in which the general surgeon and the orthopedist are competing for special rights, not only as fracture specialists, but as "bone surgeons" as well.

That this contemporary awakening in the study of fractures and their complications has proved to be an incalculable boon to this class of patients, is unquestionable. But it is also certain that the benefits that have accrued from the very simplicity and rapidity of the roentgenological diagnosis of these injuries, are not unmixed blessings. Here, as in other regions of the body which have been made translucent by roentgen rays, the tendency of the practitioner is to accept the verdict of the roentgen laboratory unconditionally, with little or no effort to correlate the findings of the laboratory with the clinical evidence, and not to question the possible fallacy of the roentgenological interpretation. In this way, the time-honored Hippocratic

Digitized by Google

habit of observation and the cultivation of the clinical sense, which are the fruits of personal observation and prolonged contact with the sick, are rapidly becoming lost arts. In this way, again, the substitution of diagnostic interpretations based upon fluoroscopic images and roentgenologic films, for the rational and methodical investigation of the patient's signs and symptoms, tends to dwarf the analytical and critical qualities of mind and to blunt the keen perceptions so necessary to a correct surgical judgment. It is, after all, the interpretation and not the roentgenographic image alone that counts. When the roentgen picture allows of diverse interpretations, as is so often the case, the laboratory report must be subordinated to the clinical facts.

In spite of the great accomplishments effected in perfecting the roentgenologic image by improved means and methods of radiation, there is still an enormous margin of possible error in differentiating the normal from the abnormal in structure, and the physiological from the pathological, in function. The margin of error will no doubt grow less with more perfect delineation and detailed presentation of the visual and graphic image, as the technique improves. It is also plain that the correct interpretation of the abnormal must be based upon a thorough appreciation of the normal. That there is plenty of room for improvement in the transillumination of the great splanchnic cavities and their contents, is well shown by the fallacies of interpretation revealed in the daily routine of radio-surgical experience.

It is in the abdomen that the growing tendency of internists and surgeons to spare their diagnostic wits and transfer their responsibility to the *x*-ray department is most apparent. It is the blind acceptance of the interpretation of the roentgenologist that is responsible in a large measure for the great and increasing surgical abuses that are committed in the abdomen where the fallacies of *x*-ray diagnosis and the liability to erroneous interpretations are greatest.

Digitized by Google

On the other hand, the perfection already attained in the reproduction of the bones of the skeleton, especially of the membral extremities, has reduced the margin of error in this particular branch to a relative minimum. But even in this chosen field, errors of interpretation frequently occur, as is well proved by the author of this volume in his instructive commentaries on the roentgenological study of the fractures and epiphyseolyses of the membral skeleton during the period of osteogenic development.

The chief purpose of the author of this volume has been to portray the normal roentgenological appearance of the epiphyses at different ages from birth to maturity, and to correlate these with the clinical findings as they came under his observation. He has been prompted to undertake this study chiefly to satisfy the requirements of his own practice in view of the frequent difficulties of roentgenologic interpretation and differentiation of epiphyseal separations, and by the discrepancies in the data furnished by the authors of the textbooks on anatomy and osteology that are classical in the medical schools of this country. In nearly all of these, the chronology of epiphyseal development is based upon the study of the ossification of the skeleton of the pre-roentgen period, when the centers of epiphyseal osteogenesis were recognized and defined by dissection, maceration, corrosion, serial sections and other modes of preparing the bones taken from dead subjects at different ages.

With the advent of the roentgen rays and of a constantly improving technique the study of growing bones has been completely transformed. Not only have the opportunities for this study been vastly increased by the inexhaustible supply of normal living material, but it has been enormously facilitated and simplified by the roentgenographic process. This study has also been improved by the greater accuracy of the roentgenogram, through which the earliest ossific deposits in the translucent epiphyses of human embryos 32 mm. long can be detected at an estimated age of nine weeks

Digitized by Google

(Pryor), long before these can be recognized in gross anatomical preparation, unless supplemented by a tedious and laborious microscopic research. The enormous advantage of this mode of recording the progress of developmental ossification are too obvious to be dwelt upon. The pre-roentgen data however, still remain of great value and are monuments to the patience and industry of the older investigators.

The importance of this particular application of roentgenology did not escape the attention of the thoughtful anatomists, embryologists, physiologists, surgeons and other specialists, who from the dawn of roentgen rays realized that the osseous system naturally afforded the most promising field for roentgenologic exploration and discovery.

Scarcely a year had passed after Roentgen had made his first announcement, in December, 1895, before a number of observers began to utilize roentgen rays in the study of bone structure. Thus on January 27, 1896, at a meeting of the Paris Academy of Sciences, MM. Lannelongue, Barthelmy and Oudin read a communication in which they called attention to the utility of roentgen rays in the study of bone pathology and bone injury.

In connection with an account[1] of the first roentgenogram made in England, by Oliver Lodge, there appeared the first demonstration of a fracture of one of the metacarpals, roentgenographed at the St. Thomas Hospital, London.

In 1896, Remy, in collaboration with Contramoulins, was directing the attention of the French Academy of Sciences to the usefulness of roentgen rays in the study of the structure and development of the skeleton in general, as well as the development and eruption of the teeth. In 1897, Behrendsen (Berlin) published his roentgenologic studies on the ossification of the human hand. In 1897, at the French Academy of Sciences, Stringer and Serbanesco

[1] Lodge, O. *Brit. M. J.*, Feb. 22, 1896.

Digitized by Google

discussed the epiphyseal causes of the disorders of bone growth and development in the light of roentgen rays. In 1896, Bade (Munich) wrote on the development of bones of the foot exhibited in roentgenograms. In 1898, Poland (London) published his great treatise on the "Traumatic Separation of Epiphyses" based on his roentgen-ray studies of the growing skeleton, in which the normal and pathologic anatomy of the epiphyses in their surgical relations are fully described. This work, together with a small roentgen atlas showing the development of the wrist and hand, is an epochal contribution and lasting memorial to the scientific initiative and enterprise of this distinguished surgeon, as it was produced at a time when the technique of roentgenology was still in its infancy. In 1898, Ranke (Munich) published a paper on the ossifications of the hand as seen with the roentgen rays. In 1899, Lambertz (Berlin) contributed a notable paper on the development of the osseous framework in fetal life as seen in serial roentgen pictures. In 1899, A. Hahn published a monograph on the deficiency or congenital aplasia of the epiphyses and its effect in stunting the growth and development of the skeleton. In 1900, Eugene Rollins Corson (Savannah, Ga.) published a series of articles on the value of roentgen rays in the study and demonstration of human anatomy, which he illustrated in a roentgenographic study of the membral epiphyses of the human carpus. This was the first anatomical work with roentgen rays in America and was characterized by the excellence of the roentgenograms which gave proof of the great advance in the technique of roentgenology in the few years that had elapsed since Roentgen's discovery. In 1901, Wilms (Basel) showed at the Geneva Surgical Society a great number of diapositives which displayed the chronological development of the epiphyses in the upper extremity; and the following year (1902) he published, in collaboration with Sick, a roentgen atlas showing the development of the bones of the skeleton by osteogenic centers from birth to maturity. Among the most praiseworthy contributions which appeared at a later

Digitized by Google

period should be mentioned the painstaking researches of Pryor (Louisville, Ky.) on the ossification of the epiphyses of the hand (1906) and the chronology and order of ossification of the bones of the human carpus (1908). His latest research on the "Difference in the Time of Development of the Centers of Ossification in the Male and Female Skeleton,"[2] is based on the study of 554 roentgenograms of the hands of infants and children from three months to fourteen years of age. He also studied the roentgenograms of 70 embryos from ten and one-half to thirty-eight weeks old, of 140 fetuses, and of 100 newborn babies from a few hours to ninety days after birth. From the analysis and comparison of the two sexes he conclusively demonstrated the great influence of sex in the ossification of the human skeleton, the female being almost invariably in advance of the male from the earliest appearance of the osteogenic centers in the embryo and throughout intrauterine life. After birth the differences are progressive up to the fusion of the epiphyses with the shaft of the long bones, which takes place in the female from three to four years in advance of the male. In this research he confirms the conclusions previously arrived at by Hasselwander (1903) and by Weisenberg (1908).

After 1900, with the steady advance in the technique, the roentgenologic studies and monographs on the ossification of the skeleton appear in increasing numbers and importance; so much so that Hasselwander, October, 1921, wrote "Die Bedeutung des Röntgenbildes für die Anatomie,"[3] a masterly review of the contributions of roentgenology to anatomy, and was able to collect a series of fifty-one papers and monographs, chiefly German, which dealt with osteogenesis, ossification and bone development in general, up to that time. His bibliography as a whole embraced 494 titles, of which seventy were devoted to technique and methods, twenty-one to textbooks

[2] *Anat. Record*, Phila., June, 1923.

[3] *Ztschr. f. d. ges. Anat.*, III, xxiii.

Digitized by Google

and atlases, and the balance, 403, referred to roentgenology in its application to human anatomy.

But this is not all, for in roentgenology the modern anthropologist has also found an invaluable aid in determining the *age* of the individual by a study of the chronology of epiphyseal ossification. The anthropologist in the pre-roentgen period depended upon the anatomical scale of ossification which had been established by the methods of gross anatomical preparations. Now, a vast amount of material has been investigated in the living subject, by the searching light of roentgenology, and the age of fusion of the various epiphyses within themselves and with the shaft or body of the bone, has been determined by the average of an immense number of roentgenographic records.

Pacini, in his article "System of Roentgen Ray Anthropometry,"[4] has revised the age data furnished by the chronological development and fusion of the epiphyseal centers of the bones of the extremities, in a laborious study of 30,000 roentgenograms. This anthropologist, however, has confined himself chiefly to determining the age of epiphyseal fusion and completed ossification of the individual bones, as an adjunct to other methods of age determination in the human subject. While these anthropological studies do not cover the systematic chronology of epiphyseal osteogenesis in detail they are of great value in completing the scale of skeletal development when combined with the averages already obtained for prenatal life by the embryologists (Felix, Keibel, Mall, Bardeen, Pryor), for postnatal life by the anatomists and pediatricians (Pryor, Rotch, Hess) and for the intermediary period, which the pure anatomists, surgical pathologists and other workers in specialized regions have investigated roentgenologically from their respective viewpoints.

It is seen by this cursory review of the activities of roentgenologists in this restricted and highly specialized department of anatomy and develop-

[4] *Jour. Radiol.*, III, 325, Aug., 1922.

Digitized by Google

mental morphology, that the ground work for a comprehensive roentgenologic study, from the embryo to maturity, has been well laid. Most of this work with some notable exceptions (Poland, Bruce, Albers—Schönberg, Grashey, Immelmann, Kohler, Hasselwander, Rieder-Rosenthal et al.) consists of fragmentary or regional studies in which the investigation has been limited to different parts of the skeleton (skull, facial bones, vertebral column, pelvis and membral extremities), in many instances with most refined thoroughness and minuteness.

There is still room, therefore, for a systematic roentgenologic treatise which shall consider the normal chronological development of the skeleton from intrauterine life to maturity, in which the student will find assembled and correlated the enormous mass of facts already acquired by the workers and investigators in the various regions of the body. If such an atlas exhibited the normal progress of ossification as influenced by age, sex, and possibly, race (white and black, in southern clinics), it would serve a most useful purpose as an aid to the professional roentgenologist himself in differentiating the normal from the abnormal, whether pathologic or traumatic.

The roentgenologist is today, next to the surgeon, the foremost exponent of the anatomy, physiology and pathology of the living organism which so profoundly differentiates the practice of medicine of the present from that of the past. With the fluoroscopic screen the roentgenologist visualizes, and with the roentgenogram he records and enlarges upon what he sees. Almost with every flash of his radiant tube, he performs a biopsy, a painless vivisection, which penetrates further than any dissection and, by what it reveals, often prevents a necropsy.

The roentgenologist, if he is to exercise his functions properly, must be prepared to collaborate with the internist and the surgeon in every one of their several specialized departments. As an interpreter of bone-shadow

Digitized by Google

records he aids the pediatrician and the orthopedist in the diagnosis, prognosis and treatment of the disorders of nutrition, metabolism and those caused by endocrine disturbances, vitamine deficiency, toxemias and infections which attack the osseous framework and interfere with normal skeletal growth. In the same way he is the right hand of the surgeon in differentiating fractures from epiphyseal separations and simple contusions or sprains, a matter of no small importance in deciding the prognosis and treatment of such injuries. His indispensable relation to the dental surgeon in the diagnosis of the developmental errors of dentition, need only be mentioned to be appreciated. Therefore, apart from all the other daily and hourly applications of roentgenology to the routine of medical practice, a knowledge of normal developmental osteogenesis is an obligate function of the roentgenologist if he be worthy of the rôle of collaborator in medicine, or claims a title beyond that of mere technician. From this special, as well as from the more general medicochirurgical point of view, it would appear that the time is ripe for a systematic and comprehensive treatise and an atlas on roentgenologic developmental osteology, planned on the lines above suggested. It is also true that the textbooks on anatomy now current in this country and abroad, should revise the data on the chronological development of the skeleton in the light of modern roentgenological research. The discrepancies between the old and the new methods of investigation should be adjusted and the usually dry and unattractive mode of presenting this subject should be changed to fit the practical importance at present attached to a knowledge of developmental osteogenesis. The normal epiphyses should be exhibited in roentgenograms as well as in the usual schematic drawings or diagrams. The effect of premature, delayed, suppressed and distorted epiphyses upon the growth and development of the skeleton, and upon the individual in general, should be portrayed in roentgenograms or in a pictorial way that would conform with contemporary methods of observation and study. In this way, what is

Digitized by Google

now an arid desert to the average medical student, would be transformed into a fruitful and refreshing oasis.

In the meantime, all contributions on developmental osteogenesis which correlate the findings of the laboratory with the facts of the clinic are as useful and desirable in roentgenologic researches as in all other divisions of medical practice. And it is in the accomplishment of this purpose that the observations and conclusions recorded by the author of this volume are calculated to serve a useful function.

Dr. Cohn's ambitions in writing this little book have been modest, with no other pretention than to present the observations and deductions drawn from his personal experience and to compare these with what has been found by others. He has sought to determine the average of normality at the various ages as obtained by the developmental data supplied by the surgical and pediatric clinics of the hospital with which he is connected, and by the juvenile dependents in homes and orphanages and from other private sources in New Orleans. The traumatisms have been contributed by the outdoor and indoor departments of the Touro Infirmary, from a mixed racial population such as the surgeon has to deal with in a southern metropolitan center. He has made no attempt to discriminate between the races, white and black, or the sexes. While the race factor may be negligible, the influence of sex on the chronology of ossification is important, as previously noted, and is well worthy of a supplementary study. The material is abundant, and if only from a pediatric and anthropological point of view, a supplementary study of these variations should be undertaken; and the author has this in view. In comparing the roentgenograms of the epiphyses at the various ages, the author has been concerned primarily with their surgical application, laying special stress, as we have already noted, on the fallacies that underlie their interpretation. He shows how in a clinically normal joint the epiphyseal lines are often mistaken for fracture lines, and how, when the fractures

Digitized by Google

and separations of the epiphyses exist clinically, they are not infrequently reported negatively by the roentgenologist. On the other hand, the number of epiphyseal separations reported roentgenologically as such, when no actual lesions exist, is striking. These errors of interpretation are fully discussed and illustrated with typical cases, in a manner that clearly emphasizes the surgical importance of the subject. These errors of interpretation most frequently occur in fractures involving the joints of the upper extremities, especially of the elbow and the wrist, which predominate in an ambulant accident clinic.

That the differential roentgenological diagnosis of joint injuries in early life has been benefited by the author's experience is well shown in his study of the elbow. Here the normal lines and angles of projection at which the epiphyses of the lower extremity of the humerus are set on the shaft, as determined by Cohn, should prove helpful in avoiding errors of interpretation. These and other original contributions to this special field of applied roentgenology are sufficient proof of the minute care with which the author has analyzed his material.

Apart from the practical value of Dr. Cohn's contribution, his constructive utilization of the material that has been placed under his control is worthy of hearty commendation as a fair example of the profit that an alert and inquiring mind can extract out of what, to many, would seem the routine drudgery of a day's work. To the young surgeon impatient for distinction and service, I would point to the legend traced in this book which reads: *Labora et spera.*

RUDOLPH MATAS.

NEW ORLEANS, LA.
July, 1924.

Digitized by Google

CONTENTS

PAGE

FOREWORD BY DR. RUDOLPH MATAS. xiv

CHAPTER

I. INTRODUCTION 1

II. THE NORMAL SHOULDER 7
Review of the Literature—Observations—Interpretations of Individual Roentgenograms at Various Ages—Summary—Illustrations of the Normal Shoulder (Figs. 1 to 24).

III. NORMAL ELBOW 25
Review of the Literature—Observations Based on the Study of the Elbow—Interpretations of Individual Roentgenograms of Normal Elbow at Various Ages—Illustrations of the Normal Elbow (Figs. 25 to 72)—Recapitulation—Surgical Importance to be Attached to the Study of Normal Elbow (Illustrated by Case Reports).

IV. NORMAL WRIST 102
Review of the Literature—Observations Based on the Study of the Normal Wrist—Interpretations of Individual Roentgenograms of the Normal Wrist at Various Ages—Illustrations of Normal Wrist at Various Ages (Figs. 107 to 132).

V. NORMAL HIP 124
Review of the Literature—Observations Based on the Study of Roentgenograms of the Normal Hip—Interpretations of Individual Roentgenograms of the Normal Hip—Illustrations of Roentgenograms of the Normal Hip at Various Ages (Figs. 136 to 170).

VI. NORMAL KNEE 154
Review of the Literature—Observations Based on the Study of Roentgenograms of the Normal Knee—Interpretations of Individual Roentgenograms of the Normal Knee at Various Ages—Summary—Illustrations of Individual Roentgenograms of Normal Knees (Figs. 171 to 208).

VII. NORMAL ANKLE 186
Review of the Literature—Observations Based on the Study of Roentgenograms of Normal Ankle—Interpretations of Individual Roentgenograms of Normal Ankle at Various Ages—Illustrations of Individual Roentgenograms of Normal Ankle (Figs. 209 to 251).

Digitized by Google

Digitized by Google

LIST OF PLATES

PLATE

Interpretation of Individual Roentgenogram of the Normal Shoulder at Various Ages . . . . . I–IV

Interpretation of Individual Roentgenogram of the Normal Elbow at Various Ages . . . . . V–XVIII

Interpretation of Individual Roentgenogram of the Normal Wrist at Various Ages . . . . . XIX–XXV

Interpretation of Individual Roentgenogram of the Normal Hip at Various Ages . . . . . XXVI–XXXVII

Interpretation of Individual Roentgenogram of the Normal Knee at Various Ages . . . . . XXXVIII–XLVIII

Interpretation of Individual Roentgenogram of the Normal Ankles at Various Ages . . . . . XLIX–LXI

Digitized by Google

Digitized by Google

LIST OF ILLUSTRATIONS

FIGURE PAGE

73 and 74. The Relation of a Plane Passed through the Middle of the Long Axis of the Shaft of the Humerus to the Capitellum. . . 68

75. A Plane at Right Angles to the Base of the Capitellum, Bisecting It, Intersects a Plane through the Middle of the Long Axis of the Shaft of the Humerus at an Angle of about 130°. 69

76. A Plane through the Long Axis of the Humerus is Intersected by a Plane through the Middle of the Long Axis of the Ulna at an Angle of Approximately 170°, when the Forearm is Extended and Supinated 69

77 Normally the Olecranon Occupies the Entire Olecranon Fossa. . 70

78A. Restoration of the Normal Position of the Internal Epicondyle . 71

78B. Displacement of the Internal Epicondyle Following Fracture . . 71

79, 80 and 81. Vicious Union Following Supracondyloid Fracture of the Humerus. This Shows Altered Relationship of the Capitellum where Vicious Union Exists 72–74

82. Vicious Union, Old Supracondyloid Fracture of the Humerus Showing in 82B Loss of Normal Lines. See Figure 76 80

83 and 84. End Result Vicious Union Supracondyloid Fracture of Humerus 79–80

85. A Comminuted Fracture of the Lower End of the Humerus Involving both Condyles. The Normal Ossifying Olecranon Epiphysis was Interpreted as a Fracture 80

86 Supracondyloid Fracture of Humerus with Backward Displacement of the Lower Fragment. 81

87. Incomplete Reduction of Supracondyloid Fracture of Humerus . . 82

88. Supracondyloid Fracture of Humerus 82

89. Incomplete Supracondyloid Fracture of Humerus 83

90. Downward Displacement of the Internal Epicondyle in a Case of Fracture of the Internal Epicondyle 84

Digitized by Google

FIGURE PAGE

91. Normal Joint which was Interpreted to be a Separation of the Olecranon Process of the Ulna 85

92 and 93. Fracture of Internal Condyle of Both Arms, after Treatment 92

94. Case xiv. Supracondyloid Fracture of Humerus after Reduction. . 93

95 and 96. Case xiv. Supracondyloid Fracture of Humerus. End Results. 94–95

97 and 98. Case xv. Old Supracondyloid Fracture of Left Humerus. End Results. 96

99. Case xvi. Supracondyloid Fracture of Humerus. End Result . . . 97

100. Case xvii. Posterior Dislocation of Elbow and Supracondyloid Fracture. End Result 98

101 and 102. Case xviii. Fracture of Internal Condyle of Humerus. End Results. 99

103 and 104. Case xix. Supracondyloid Fracture of Humerus. End Results 100

105 and 106. Case xx. Supracondyloid Fracture of Humerus. End Results. 101

Digitized by Google

NORMAL BONES AND JOINTS

Chapter I

INTRODUCTION

Every publication should have a definite objective—an idea to convey. The purpose of this work will be to present a study of normal joints from a roentgenological standpoint and to submit our findings as a standard for comparison. It is hoped that the surgical importance of such a standard will be appreciated. Others must have suffered the embarrassment which we have experienced when confronted with questions relating to the epiphyses.

A great deal of confusion exists to-day in regard to (1) the number of epiphyses for a given bone; (2) the earliest evidence of ossification within the respective epiphyses; (3) the relationship of the respective epiphyses to one another at varying periods during the time necessary for the completion of ossification; (4) the time at which union between the completely ossified epiphyses and the diaphysis occurs.

Reference to our standard textbooks on surgery and anatomy will convince anyone that all of these questions are answered in a different manner by various authors. Particularly is this true with reference to the question of the number of epiphyses for a given bone, and the time of complete ossification.

In many textbooks, the variations cover a period of several years in answer to the latter question. In others, there is evidence of reiteration of the statements of previous authors, without the benefit of quotations.

Our literature, at the present time, does not contain a monograph devoted to the subject of the roentgenological aspect of epiphyseal develop-

Digitized by Google

ment; to the comparative relationship of the epiphyses to the diaphysis; and to the study of this development at all ages—from birth to the time of complete ossification.

Many years ago, John Poland undertook this work, and for some reason his published works include a complete study of only one joint, that is, the wrist and the bones of the hand. This masterpiece, which would have been, if completed, a great help to the men of his generation, unfortunately is out of print, and is comparatively little known by the profession at large. The prophetic words of Poland, written more than twenty-five years ago, illustrated the vision of the man: "The new skiagraph by Roentgen's process will undoubtedly, in the near future, furnish us with very exact information as to the appearance of the centers of ossification of the epiphyses, their position and form at different ages, and lastly, as to the time of union of the epiphyses to the diaphysis."

Again in 1902, Francis H. Williams stated: "The *x*-rays are of assistance in pointing out delayed union of the epiphyses, and when we are familiar with the appearance to be expected of the epiphyses at different ages—that is to say, when we have made a physiological scale, we may find that we have gained a method of estimating the general condition of the younger patients in regard to their development."

P. H. Kreuscher[1] in 1918 concluded that "a thorough knowledge of the normal structures and their time of appearance is necessary intelligently to treat the abnormal conditions," and Roland Hammond[2] stated that "the normal appearance on the Roentgen plate should be familiar to everyone and it would not be a bad idea for each practitioner to have a set of Roent-

[1] Kreuscher, P. H. A study of the development of the epiphysis. *Surg., Gynec. & Obst.*, 1918, xxvii, v, 480.

[2] Hammond, R. The Rœntgen anatomy of the epiphyses. *Providence M. J.*, 1907, viii, 163.

Digitized by Google

gen plates or pictures to which he might refer as he would to his textbook of anatomy."

Statements like these, which should have been sufficient to encourage many to take up this field of work, seemed to have failed. This failure, in part, was due to the fact that surgeons in the early days were so overwhelmed by the fact that the *x*-ray demonstrated the exact location of fractures in parts of the bone other than the cartilaginous epiphyses, that they did not stop to consider the study of individual epiphyses.

Or, one might turn to Lucid[3] (1899), to obtain the answer: "It is indeed strange that so little has been written upon the subject of epiphyseal separations of the ends of the humerus, either by remote or modern surgeons, but the epiphyseal structures are small and we are very conscious of the fact that nowadays most surgeons are looking for larger game."

Our predecessors were not so fortunate as we in having the valuable assistance of roentgenograms. In spite of this handicap, a review of some of the authorities of the immediate pre-*x*-ray period will demonstrate how well they utilized their knowledge of anatomy for the benefit of the patient. A similar review of more recent literature will convince any observer that in this particular field, the field of the epiphyses and their development, the true value of the *x*-ray has not been utilized, nor realized by the majority of surgeons, roentgenologists and others for whom such a study is potentially so pregnant.

Wheelhouse in 1885 stated: "You should never consider your knowledge of the bones to be perfect until you have made the anatomy of the epiphyses as thorough as that of every other point connected with them."

Professor Smith said: "When the surgeon is called upon for his opinion respecting the nature of injuries occurring in the vicinity of the larger joints

[3] Lucid, M. Epiphyseal separation of the ends of the humerus. *N. York M. J.*, 1899, LXX.

Digitized by Google

in early life, he will find that the knowledge of the anatomy of the epiphyses is of the greatest importance."

Jonathan Hutchinson in 1885 said: "I am not far wrong in saying that in current manuals on surgery of the day, you will find comparatively little information with reference to these injuries."[4]

Modern textbooks on anatomy and surgery pay scant attention to this subject. Given a patient with an injury to one of the joints, difficulties are certain to arise in an effort at interpretation. *It is not possible for the roentgenologists to say in a given case that the patient has not a fracture within the cartilaginous epiphyses, provided there is no disturbance of the normal relationship which should exist between the epiphyses and the diaphysis.* This statement is based on the fact that cartilage does not leave a definite shadow in the picture, and therefore, a line of fracture within this cartilage would not be manifest. This is very important from a surgical standpoint; and it is our conviction that when the clinical manifestations of fracture are evident in the young, the roentgenogram should not deter us from the treatment of such a case as a fracture. Furthermore, if the above statement is true, it becomes necessary for us to have a definite notion of the normal relationship which should exist between the epiphyses and diaphysis at given ages.

Without such a standard for comparison, the roentgenologist is apt to consider many normal joints as "separations" or even as fractures. Some are willing to believe that it is unnecessary to present a series of normal joints at varying ages for the purpose of comparison, as one can take pictures of the corresponding joint on the opposite side at the same time. Such a procedure is undesirable; (1) because it is an admission of ignorance; (2) because it will be a source of unnecessary expense to the patient and lastly (3) it

[4] Hutchinson, J. Injuries to the epiphyses. *Med. Press & Circ.*, Lond., 1885, n. s. XL, 461.

Digitized by Google

will not be carried out, for it has not been in the past. Many will continue to do as they have in the past—make a shrewd guess. Often this guess will lead them to the statement that an epiphyseal separation exists, or that it is a possibility.

Our own experience justifies the statement that many cases which we have treated as so-called epiphyseal separations were in reality normal joints; and many of them were fractures.

It might not be out of place at this point to state that it is our conviction that so-called epiphyseal separations are fractures through the epiphyseal cartilage and the displacement is such as would occur in any fracture. The idea of epiphyseal separation can only be supported by those who look upon the relationship of the epiphysis and the diaphysis as a rather loose junction, whereas, it is a cartilaginous union which is very firm.

It is interesting to note that Delpech and Malgaigne (1859) stated as their opinion that "such separations do not differ in any particular respect from fracture and that there is no importance in attempting to distinguish between them."

The value of proper knowledge of the roentgenographic appearance of the normally developed joint can hardly be overestimated. The value of this knowledge to anatomists, surgeons, pediatrists, orthopedists, endocrinologists and roentgenologists is becoming increasingly important. Many problems can probably be solved by the pediatrists and endocrinologists through a study of the joints of their patients in the light of such a standard for comparison.

The effect of diet, the effect of metabolic diseases and like questions certainly have a bearing and will be helped by a knowledge of the normal.

It is interesting to note that up to the present time there is a marked variation noted regarding the time of ossification of certain of the epiphyses. *The period of complete ossification probably is different under different climatic*

Digitized by Google

conditions; this also will give an opportunity for a study of this subject in colder climates. The literature on the subject is misleading. There is no agreement among authorities as to the period at which union occurs, or the exact number of epiphyses.

Our early interest in this subject arose through the necessity of answering two types of questions. One, the didactic question of classes, "When do the epiphyses unite?" This question always proved embarrassing, and many times led to the avoidance of the issue. The second was the clinical question, "When is an injury to a joint in the young a fracture or an epiphyseal operation, and when is it an injury only of the soft parts?"

Progress results from applying the lessons of personal experience and information gained through the knowledge of the literature of the past and present. Through progressive methods alone can the patients obtain the best results in our hands.

Errors creep in under the very best conditions, but at the present time the error in the diagnosis of injuries about joints due to ignorance or lack of appreciation of fundamentals, such as we believe this study to represent, is not excusable. We believe that by properly interpreting a skiagraph the roentgenologist should be in a position to report if a deformity will result with permanent impairment of function, unless the relationship of the epiphysis to the diaphysis is corrected. This, we believe, will be conclusively shown by certain lines which we have developed as a result of the study of these cases. The epiphyses bear a definite relationship to one another and to the diaphysis.

An effort will be made to present this subject of normal joints from a roentgenological standpoint, laying particular stress on the surgical importance of such knowledge. It is our hope that it will prove as useful to other teachers and surgeons as it has to us.

Digitized by Google

Chapter II

THE NORMAL SHOULDER

In accordance with the general plan of the work, this and other chapters will be subdivided into parts.

I. A review of the literature. In each instance this review will prove the justification for the present volume.

II. Conclusions based on the study of the normal joints in question.

III. Descriptive findings of individual roentgenograms of particular joints at various ages.

IV. The importance to be attached to such a study from the surgical standpoint and suggestions of its value to others.

Review of the Literature

Piersol, in his work on anatomy, states: "There are two or three (centers) for the upper, a chief one for the head coming soon after birth and sometimes sooner. In the third year ossification begins in the greater tuberosity, and another point may appear somewhat later in the lesser one. At five all of the centers for this end may become one, making a cap for the top of the shaft, which later extends into the head. The upper end joins at about nineteen, the line of union being lost at twenty or twenty-one."

Gray's Anatomy gives the following: "During the first year, sometimes before birth, ossification commences in the head of the bone and during the third year the center for the tuberosity makes its appearance, usually by a single ossification point, but sometimes, according to Béclard, by one for each tuberosity, that for the lesser being the smaller and not appearing until the fifth year. By the sixth year the centers for the head and tuberosities have increased in size and become joined, so as to form a single large epiphysis. The upper epiphysis is not united until the twentieth year."

Digitized by Google

Preston's work on fractures is in complete agreement in word and sentiment with Gray's Anatomy.

Stimson states: "The upper epiphysis of the humerus comprises the head and the tuberosities."

Comment. It is interesting to note that Stimson speaks as though he believed that there was a single epiphysis.

Cotton does not venture an opinion on the subject under the heading "Separation of the Epiphysis" (humerus) in his work on "Dislocations and Joint Fractures."

In Morris' Anatomy we find: "Single centers appear for the head in the first year, for the greater tuberosity in the third year and for the small tuberosity in the fifth year, though sometimes the latter ossifies by an extension from the greater tuberosity. These three nuclei coalesce at six years to form a single epiphysis which joins the shaft about the twentieth year."

Lewis' "Gray" and Spitzka's "Gray" as well as Gerrish's Anatomy, agree in every detail with the above.

Cunningham states: "Within the first six months after birth a center usually appears for the head; this is succeeded by one for the greater tuberosity during the second or third year. These soon coalesce and a third center for the small tuberosity begins to appear about the end of the third year or may be delayed until the fourth or fifth year. These three centers are all blended by the seventh year and form an epiphysis which ultimately unites with the shaft about the age of twenty-five."

According to Eisendrath the upper epiphysis joins the shaft at the age of twenty.

Williams, in a chapter on "Development of the Skeleton," does not mention particular ages at which union of the epiphysis and shaft takes place. No pictures are given. Von Bergmann, Senn, Park and many recent

Digitized by Google

standard works on surgery were consulted for information and nothing was found that would be helpful on this subject.

Choyce gives the following: "The upper end of the humerus is formed of three separate epiphyses, for the head and greater and lesser tuberosities, the centers for which appear respectively at six months, two years, and three years after birth. They are all united at the end of the second year to form a single epiphysis which joins the shaft at the age of twenty-five."

Roberts and Kelly state: "The humerus is developed from a center of ossification for the diaphysis, which appears during the eighth week of fetal life, and six or seven secondary centers for the extremities which appear after birth, the epiphysis being cartilaginous. During the first year the centers appear in the following order: *upper epiphysis for the head*, the capitellum, *the greater tuberosity*, *the lesser tuberosity*, the trochlea, the external and internal epicondyles, which appear between the tenth and twelfth years. Complete ossification and disappearance of the synchondroses from the twentieth to the twenty-second year."

Poland's work gives the impression that he believed that there was only one epiphysis for the upper end of the humerus. (See Poland's table on date of appearance of the centers of ossification.)

For convenience it may here be stated that Poland considered that the upper epiphysis (head) appeared about "fifteen months after birth" and that union between diaphysis and epiphysis occurred about the "eighteenth to the twenty-second year."

Of all the authorities mentioned, two alone seem to be of the opinion that only *one* definite epiphysis exists—Poland and Stimson.

Digitized by Google

TABLE I

TABLE OF APPEARANCE OF CENTERS IN THE UPPER END OF THE HUMERUS, ACCORDING TO VARIOUS AUTHORS

Author	Head	Greater Tuberosity	Lesser Tuberosity	Union with Shaft
Poland	15 mos.	.....	.....	18–22 yrs.
Piersol	Soon after birth (At 5 yrs. all	3rd yr. have united to form o	Later than 3rd yr. ne epiphysis)	20–21 yrs.
Gray	During 1st yr. (All coalesce	3rd yr. to form a single epiph	3rd yr. ysis) Sometimes as late as the 5th or 6th yr.	20th yr.
Morris	1st yr.	3rd yr.	5th yr. Sometimes this is an extension of the greater tuberosity	20th yr.
Lewis, Gray, Spitzka, Gerrish	Same as above			
Cunningham	During first 6 mos.	2nd or 3rd yr.	3rd to 5th yr.	25 yrs.
Eisendrath				20 yrs.
Choyce	(All unite by 6 mos.	the 2nd yr.) 2 yrs.	3 yrs.	25 yrs.
Preston	Gi	ves the same as Gray's	Anatomy.	
Roberts and Kelly	1st yr.	1st yr.	1st yr.	20–22 yrs.
Isidore Cohn	Roentgenologically there is only one definite epiphysis. Ossification is certainly evident at seven weeks after birth. Complete union with the shaft takes place between the nineteenth and twentieth years. The greater tuberosity seems to be a downward growth from the head. In none of our pictures have we been able to see a separate center of ossification for the lesser tuberosity.			

Digitized by Google

Observations Based on a Study of the Normal Shoulder

When examining roentgenograms of the shoulder in the young one must know how many separate epiphyses are normally present, when each one begins to ossify, and when complete ossification and union take place.

Roentgenograms of the Shoulder, Including the Upper Limit of the Humerus, the Scapula and the Clavicle

We have observed one definite epiphysis for the upper end of the humerus. There is a possibility that the greater tuberosity develops from a separate epiphysis, but our observations lead us to believe that the greater tuberosity is a downward overgrowth from the head of the humerus.

A separate epiphysis for the lesser tuberosity has not been seen in our series, and if it does occur it must be a rare finding and cannot be considered the normal occurrence. There is a separate epiphysis for the acromion process and one for the coracoid of the scapula.

The upper epiphysis is not evident roentgenographically at birth, but it appears soon after. The earliest period at which we have seen ossification within the epiphysis for the head, is seven weeks. At this time, it is rather widely separated from the upper limit of the shaft and is of an elliptical shape. The upper limit of the shaft is represented by a double inclined plane (Fig. 1).

The glenoid fossa, the acromion process (not the epiphysis of the acromion process) and the clavicle are ossified to the same degree as the diaphysis of the humerus.

During the first two years the epiphysis for the head is the only one which shows any evidence of ossification. The size of this epiphysis increases markedly during this period, and it becomes more closely approximated to the shaft.

The coracoid becomes evident as a separate ossifying epiphysis about the second year (Fig. 5).

Digitized by Google

At three years of age, the upper epiphysis of the humerus has increased markedly in size, and on the outer lower portion there can be noted a smaller elliptical mass which, by the methods at our command, cannot be said to be a separate epiphysis in the majority of instances (Fig. 6).

It cannot be maintained that the greater tuberosity does not originate from a separate center occasionally. In the majority of instances, it seems to be a downward outgrowth from the head. Whether a separate epiphysis exists or not, it is certain that at four, five, six and seven years it has become definitely a part of the upper epiphysis of the humerus which by this time forms a tongue and groove joint with the shaft (Fig. 7).

The coracoid process, which was mentioned as having been evident at the second year, is increased somewhat by the third year (Fig. 6). Few changes are evident in the upper end of the humerus between the ages of three and seven. By this time, almost complete ossification has taken place within the epiphysis for the upper end of the humerus, and we find the epiphysis and the shaft closely approximated (Fig. 8).

As ossification progresses in the upper epiphysis the cartilaginous line diminishes in size until at the age of eleven or twelve, there is evident only a faint line. Ossification progresses more rapidly on the inner side than in the area of the greater tuberosity; here there is still to be seen a separation which might easily be misinterpreted as a fracture.

About the ninth year, a rather puzzling appearance is noted in some normal shoulders (Fig. 10). Examining it carefully, one finds that there is a constriction below the head, and lower down on the roentgenogram there is a definite wedge-shaped "fragment." It was difficult to interpret this particular appearance until it was realized that possibly it might be due to two things, position and an optical illusion.

In order to determine whether the apparent lines were due to position and nothing else, it was determined to take the same shoulder in several positions.

Digitized by Google

This proved conclusively that the appearance is an optical illusion, the result of looking through the epiphysis at different angles (Figs. 22, 23, 24).

Visualize a cross section of a tongue and groove joint and you will have the ordinary roentgenogram as obtained. If now this same joint be rotated through an arc of 90° you will visualize the appearance which one sees often in normal shoulders—the appearance is so misleading that it is often misinterpreted. Before arriving at a diagnosis of fracture of the surgical neck of the humerus in the young, roentgenograms must be made in several planes.

At the age of fourteen years and six months we note a definite center of ossification for the acromion process. This is very important because this epiphysis is often mistaken for a fracture.

By the eighteenth year, this epiphysis has completely ossified and there is bony union between the epiphysis and the scapula proper (Figs. 15, 17, 18, 19, 20).

During this period there is danger of falling into error in interpreting roentgen-ray findings.

At this time also we note that the greater tuberosity of the humerus shows a distinct line which might be mistaken for a fracture (Figs. 15 to 20).

At the age of eighteen years and seven months (Fig. 18) all of the epiphyses are united to the shaft, there being only the slightest line of demarcation at the lower level of the greater tuberosity of the humerus; this line is irregular and may extend through the diameter of the shaft (Fig. 20).

By the twentieth year all of the epiphyses are completely ossified and the shoulder has the appearance of the adult normal type (Fig. 21).

Digitized by Google

Digitized by Google

Interpretation of Individual Roentgenograms of the Normal Shoulder at Various Ages (Plates i–iv)

Digitized by Google

PLATE I

Seven Weeks (Fig. 1). At this time there is only one epiphysis for the upper end of the humerus and this is a small elliptical mass widely separated from the shaft. The acromion process, the glenoid fossa and the clavicle are all well ossified. There is no evidence of a coracoid process.

Five Months (Figs. 2 and 3). The only change noted is a marked increase in the size of the upper epiphysis, which is now at least twice the size of the same shadow at seven weeks.

Thirteen Months (Fig. 4). The upper epiphysis has increased in size. No other changes are noted in the other structures.

Two Years (Fig. 5). The only evident change is a small shadow which may be the beginning of ossification within the coracoid.

Summary. During the first two years ossification is noted in one epiphysis for the upper end of the humerus. The other structures show evidence of ossification of all the prominences of the scapula, except the coracoid which shows slight evidence of ossification only toward the latter part of the second year.

Three Years (Fig. 6). The upper end of the shaft has changed its appearance, from the transverse line, to an angular appearance, sloping downward and outward and downward and inward from a plane passed through the outer third of the shaft of the humerus. The inner slope of this upper end of the shaft is covered in about two-thirds of its upper aspect by the ossified upper epiphysis. There is a shadow in the outer portion of the epiphysis, which seems to make the epiphysis fit over the tongue-grooved effect of the shaft.

This shadow in the outer portion of the upper epiphysis may be a separate epiphysis for the greater tuberosity or it may be a downward projection of the upper epiphysis to form the greater tuberosity as a portion of the original epiphysis for the head.

The coracoid by this time has grown to a rather large size.

Digitized by Google

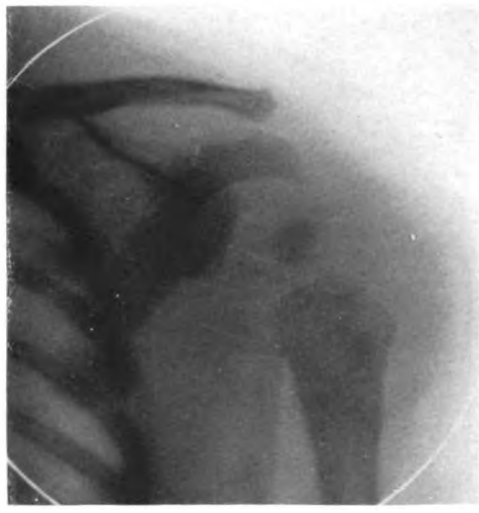


FIG. 1. SEVEN WEEKS.

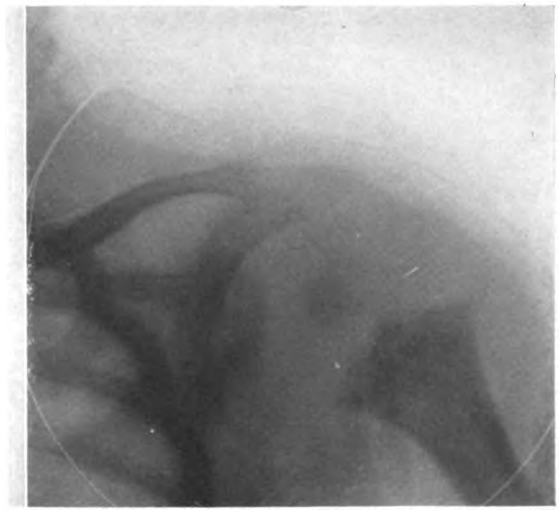


FIG. 2. FIVE MONTHS.

FIG. 3. FIVE MONTHS.

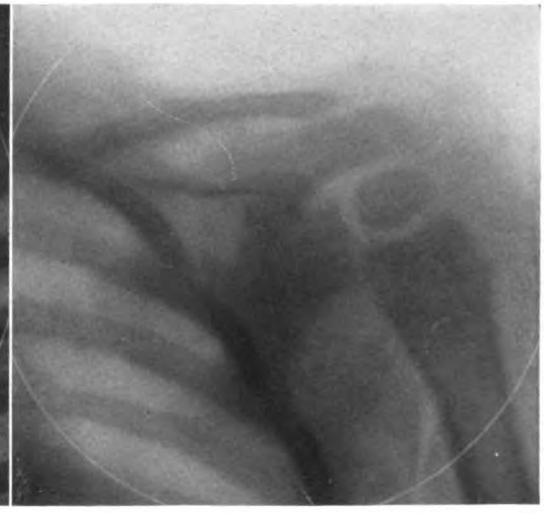


FIG. 4. THIRTEEN MONTHS.

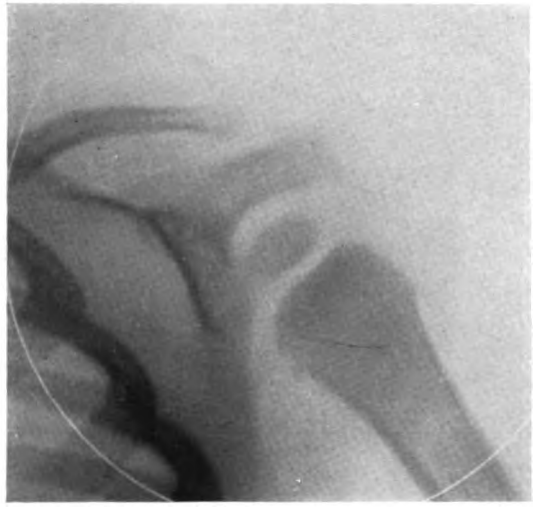


FIG. 5. TWO YEARS.

FIG. 6. THREE YEARS.

Digitized by Google

PLATE II

Four Years and Six Months (Fig. 7). The upper epiphysis covers more than two-thirds of the upper end of the diaphysis. The tongue-grooved effect is more evident now than at previous periods. If the ossifying portion of the upper epiphysis, which forms the greater tuberosity, is a separate epiphysis, there is certainly no definite line of demarcation between the two.

Seven Years (Fig. 8). The upward projection of the diaphysis is entirely covered by the ossified upper epiphysis. If originally there were separate epiphyses for the head and greater tuberosity, the two have certainly united at this time. The coracoid has increased markedly in size.

Eight Years (Fig. 9). There is closer approximation between the shaft and the epiphysis. Ossification from the shaft seems to proceed up into the epiphysis. The coracoid process is larger than in previous years.

Eight Years and Ten Months (Fig. 10). This roentgenogram gives the impression that the epiphysis for the head is separated from the head by a wedge; this is due to polarization of the shaft. (For further details see Fig. 11.)

Nine Years and Ten Months (Fig. 11). The diaphysis seems to be separated from the epiphysis for the head, by a triangular or wedge-shaped shadow. The impression given is that this wedge is separate and distinct from the shaft and also from the head.

This is not the true state of affairs, but the appearance is rather an optical illusion due to the position of the arm when the roentgenogram was taken.

The lower part of the head represents the epiphyseal line and what afterwards becomes the anatomic neck.

The wedge-shaped shadow represents the greater tuberosity. The same may be said at the age of ten years and ten months (Fig. 12).

Digitized by Google

FIG. 7. FOUR YEARS, SEVEN MONTHS.

FIG. 8. SEVEN YEARS.

FIG. 9. EIGHT YEARS.

FIG. 10. EIGHT YEARS, TEN MONTHS.

FIG. 11. NINE YEARS, TEN MONTHS.

FIG. 12. TEN YEARS, TEN MONTHS.

Digitized by Google

PLATE III

Eleven Years and Six Months (Fig. 13). There is closer approximation between the shaft and the epiphysis. At this time there is no evidence of ossification within the epiphysis of the acromion process.

Fourteen Years (Fig. 14). There is closer approximation of epiphysis and diaphysis, but no evidence of ossification between the two. The coracoid process is well developed. There is still no evidence of ossification of the epiphysis for the acromion.

Fourteen Years and Six Months (Fig. 15). This is similar to the appearance at fourteen years, with the exception that there is a well-developed acromion process. The epiphysis is separated by a definite line from the acromion proper.

Fourteen Years and Eight Months (Fig. 16). There is complete ossification of the upper epiphysis of the humerus, almost complete obliteration of the epiphyseal line except in the lower portion of the greater tuberosity, which is still separated by a well-defined line.

At this age, the acromion epiphysis seems completely ossified and united to the remainder of the acromion. This is an occasional finding.

Fifteen Years and Four Months (Fig. 17). The wedge-shaped appearance of the upper end of the shaft is here replaced by an almost flat top of the shaft, superimposed on which is the ossified upper epiphysis which is not united yet to the shaft. The acromion is not united to its epiphysis, although the epiphysis shows evidence of almost complete ossification.

Sixteen Years and Ten Months (Fig. 18). The greater tuberosity seems not to be united entirely with the diaphysis. Between the remaining portion of the epiphysis and diaphysis union seems complete.

The epiphyseal line between the acromion and the diaphysis of the scapula is still very marked.

Digitized by Google

FIG. 13. ELEVEN YEARS, SIX MONTHS.

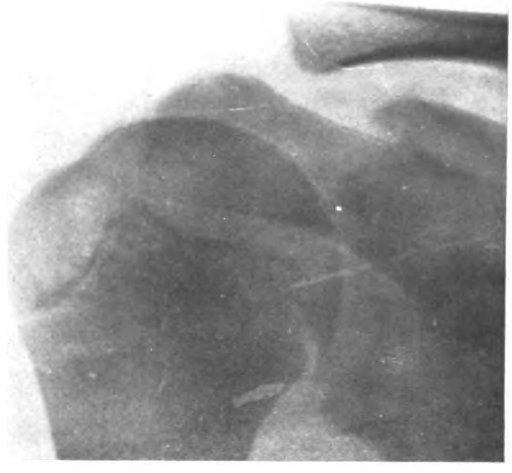


FIG. 14. FOURTEEN YEARS.

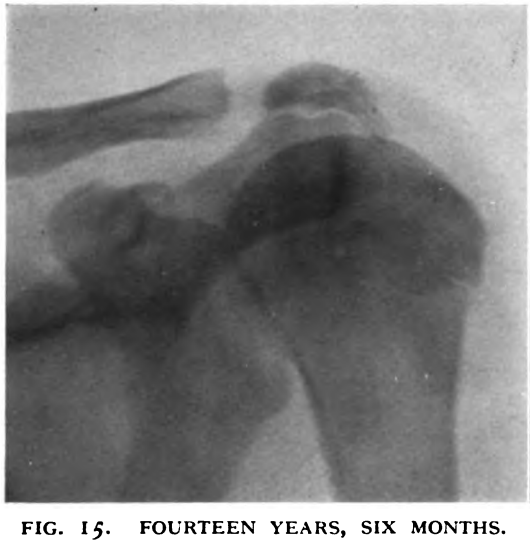


FIG. 15. FOURTEEN YEARS, SIX MONTHS.

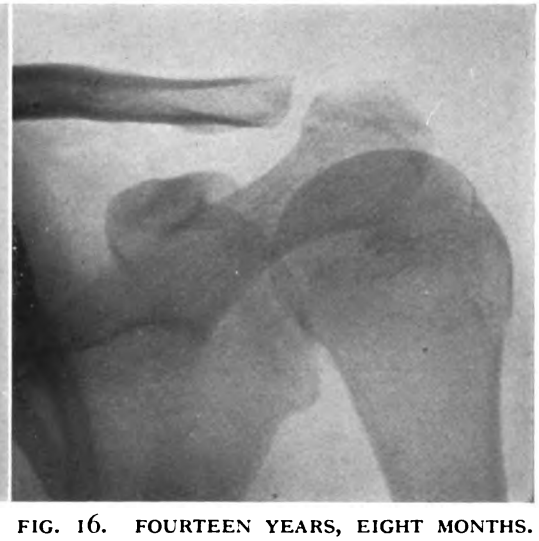


FIG. 16. FOURTEEN YEARS, EIGHT MONTHS.

FIG. 17. FIFTEEN YEARS, FOUR MONTHS.

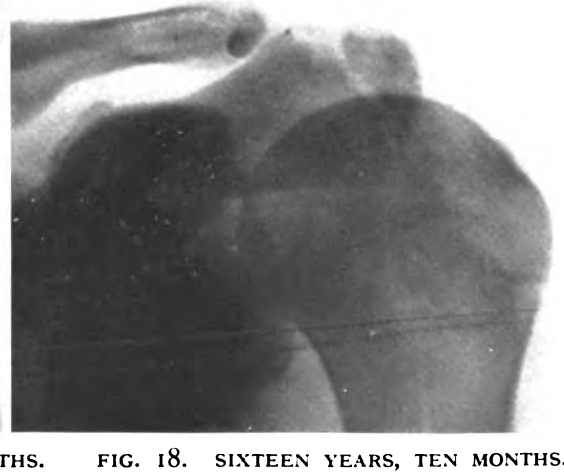


FIG. 18. SIXTEEN YEARS, TEN MONTHS.

Digitized by Google

PLATE IV

Seventeen Years and Six Months (Fig. 19). Incomplete union of the epiphysis and diaphysis. The acromion process is not yet united to the shaft.

Eighteen Years and Seven Months (Fig. 20). Complete ossification of the epiphysis and almost complete union of the epiphysis and shaft. Scapula ossified throughout.

Twenty Years (Fig. 21). Complete ossification and union of the respective epiphyses and diaphyses.

Figures 22, 23 and 24 represent the altered appearance of the same shoulder caused by a change in its position.

Digitized by Google

FIG. 19. SEVENTEEN YEARS, SIX MONTHS.

FIG. 20. EIGHTEEN YEARS, SEVEN MONTHS.

FIG. 21. TWENTY YEARS.

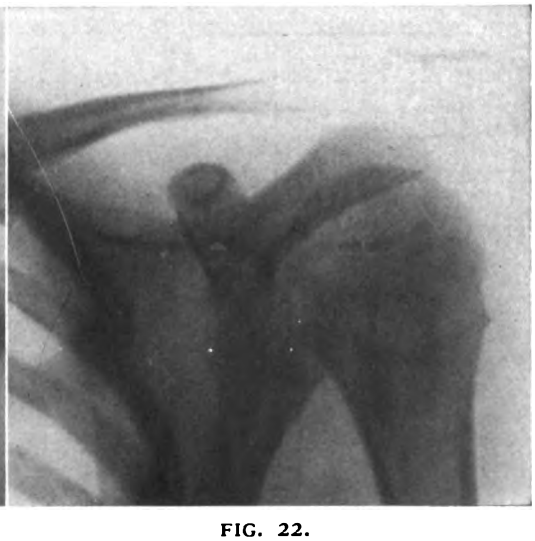


FIG. 22.

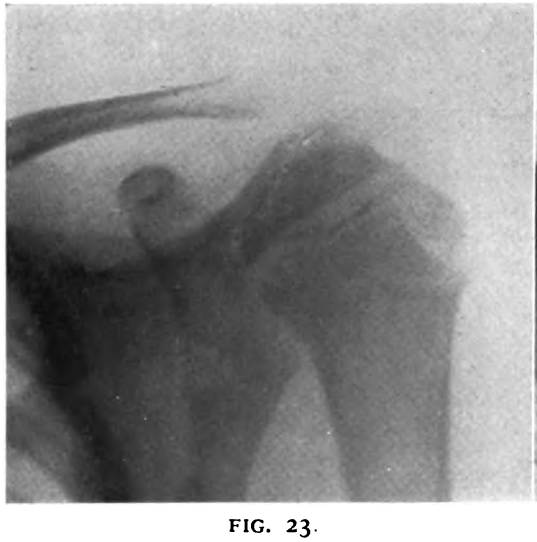


FIG. 23.

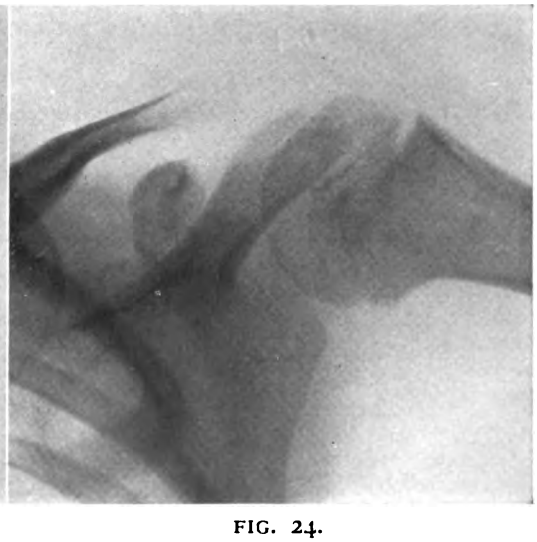


FIG. 24.

FIGS. 22, 23 AND 24 REPRESENT THE ALTERED APPEARANCE OF THE SAME SHOULDER, CAUSED BY A CHANGE IN ITS POSITION.

Digitized by Google

Summary

1. There is only one definite epiphysis for the upper end of the humerus.

2. This is not present at birth—ossification begins soon after birth, about the sixth or seventh week.

3. The greater tuberosity is most likely not a separate epiphysis but a downward outgrowth from the head.

4. The lesser tuberosity is rarely a separate epiphysis.

5. The coracoid begins to ossify during the second year.

6. Ossification for the acromion begins in the epiphysis during the fourteenth year and is completed by the eighteenth year.

7. Complete ossification within the upper epiphysis is evident about the nineteenth year. There is no trace of the epiphyseal line at the twentieth year.

8. The dangers of misinterpreting normal shoulder roentgenograms are many:

(*a*) The roentgenogram is not a dependable source of information in regard to injuries about the shoulder during the early years of life; at this period the epiphyses are largely cartilaginous.

(*b*) Lack of appreciation of the varied appearances of the same normal shoulder, when roentgenograms are taken at different angles, will lead to many errors. It becomes our duty to take views of the shoulder in the young at different degrees of rotation.

(*c*) The acromion epiphysis between the ages of fourteen and eighteen is often mistaken for a fracture.

To avoid these sources of error a closer coordination of clinical data and *x*-ray findings will be necessary. It is also necessary that we know the approximate relationship between the epiphysis and shaft at varying ages in order to avoid the recurring error of calling normal joints, epiphyseal separations. *These injuries occur more often in the minds of the reader than in actual practice.*

Digitized by Google

Chapter III

THE NORMAL ELBOW

Review of the Literature

John Poland, in his work on "Traumatic Separation of the Epiphyses," was content to state that separations of the epiphyses "can only occur in patients below twenty-one or twenty-three years of age, before the epiphyses have become united by bone to the shaft."

A. H. Tubby, in 1899, writing on "Traumatic Separation of the Epiphyses of the Upper Extremity," states: "The subject of traumatic separation of the epiphyses is now receiving a fuller measure of attention than formerly. Separations of the epiphyses are even more important than fractures, from their occurrence in young life and the important effects that may ensue in regard to the subsequent growth on the bone."

Case reports and museum specimens of epiphyseal separations are included in this paper, but no allusion is made to the ages at which various epiphyses appear, nor to ages of ossification, and no mention is made of the appearance of these lines and the possibility of misinterpreting them as fractures.

"It is indeed strange that so little has been written upon the subject of epiphyseal separation of the ends of the humerus, either by remote or modern surgeons, but the epiphyseal structures are small and we are ever conscious of the fact that nowadays most surgeons are looking for larger game," said Lucid[1] in 1899. He added: "Ossification begins in the radial portion of the articular surface at the end of the second year; in the trochlear portion at the twelfth year, the internal condyle at the fifth year, and the external epicondyle at the fourteenth year. At the sixteenth and seventeenth years of life all of the centers are joined to each other and to the shaft, except the inner epicondyle, which does not unite with the shaft until the eighteenth year."

[1] Lucid, M. Epiphyseal separation of the ends of the humerus. *N. York M. J.*, 1899, LXX.

Digitized by Google

Fowler, writing on the "Separation of the Epiphyses of the Lower Extremity of the Humerus,"[2] in 1899, under the heading of anatomy, said: "The lower epiphysis of the humerus includes both epicondyles, the epiphyseal line being fairly straight and crossing the bone just above the two epicondyles. Directly over it lies the olecranon fossa. The epiphysis has, at first, five separate centers of ossification. These are subsequently reduced to three. The ossification in the capitellum is said to begin during the third year."

Hutchinson has found it (capitellum) at eighteen months and Farabeuf says that "it usually occurs during the second year." The width of the epiphyses increases during the first few years. The depth increases slightly. The nucleus over the internal epicondyle appears at the fifth year. The third nucleus over the trochlea appears in the eleventh or twelfth year. A small separate nucleus appears over the external epicondyle. Fusion with the shaft is completed in the sixteenth or seventeenth year.

Modern anatomies and textbooks on surgery in general pay scant attention to this subject, as will be noted from the following:

The lower end of the humerus develops in the following manner. At the end of the second year ossification commences in the radial portion of the articular surface (capitellum) and from this point extends inward, so as to form the chief part of the articular end of the bone. The center for the inner part of the articular surface does not appear until about the fifth year and for the external part not until the thirteenth or fourteenth year. At about sixteen or seventeen years, the external condyle and both portions of the articular surfaces, having already joined, unite with the shaft. At the eighteenth year the internal condyle becomes joined to the shaft.

The centers in the lower end of the humerus appear thus according to various authors: In the radial portion of the articular surface (capitellum),

[2] Fowler, R. S. *Brooklyn M. J.*, 1899, XIII, 209.

Digitized by Google

at the end of the second year (Knox); end of the second and third year (Cunningham); end of the second year (Gray); center for the mesial half of the trochlea at the twelfth year (Knox); eleventh to twelfth year (Cunningham); twelfth year (Gray). Internal condyle: fifth year (Knox); fifth year (Cunningham); fifth year (Gray). External condyle: thirteenth or fourteenth year (Knox); twelfth year (Cunningham); thirteenth year (Gray).

The external condyle and both articular surfaces unite between the sixteenth and seventeenth year (Gray); sixteenth and seventeenth year (Cunningham); sixteenth and seventeenth year (Knox).

TABLE II

TIME OF APPEARANCE OF CENTERS IN THE LOWER END OF THE HUMERUS ACCORDING TO VARIOUS AUTHORS

Author	Capitellum	Internal Epicondyle	External Epicondyle	Trochlea	Complete Ossification
Lucid (1899).....	End of 2nd yr.	5th yr.	14th yr.	12th yr.	16th to 17th yr.
Gray.....	End of 2nd yr.	5th yr.	13th to 16th yr.	12th yr.	
Knox.....	End of 2nd yr.	5th yr.	13th yr.	11th to 12th yr.	15th yr.
Cunningham.....	End of 2nd yr.		12th yr.	12th yr.	16th to 17th yr.
Cotton.....	1 ½yrs.	5th yr.	12th to 14th yr.		
Scudder.....	Generalities	Only			17th yr.
Roberts and Kelly.....	1st yr.	10th to 12th yr.	10th to 12th yr.	10th to 12th yr.	20th to 22nd yr.
Stimson.....	1st and 2nd yrs.			Generalities	
Ashhurst.....	1st ½ yr.	6th yr.	12th yr. not constant	11th yr.	15th yr.
Isidore Cohn.....	17th mo.	Appears at times at 7 yrs., but is not constantly present until the 11th yr.	This is not ordinarily a separate epiphysis	May appear as early as 8 yrs., but is not constantly present until the 11th yr.	15th to 17th yr.

Digitized by Google

The internal condyle unites with the diaphysis at about the fifteenth year (Knox); from the eighteenth to the nineteenth year (Cunningham); eighteenth year (Gray). The epiphysis unites with the shaft about the fifteenth year or before the outer condyle unites with the articular surfaces (Knox); from the sixteenth to the seventeenth year (Cunningham); about the fifteenth year, or the same as Knox.

Cotton, writing on joint fractures and dislocations in 1910 under the title, "Anatomy of the Epiphysis," states: "At birth, and up to two or three years of age, the whole lower end of the humerus is a cartilaginous mass in which an ossification center appears at the outer side at about one and a half years of age.

"By four or five years of age the external condyle has become a definite structure and a cleavage line occurs in the cartilage that has been formed. The internal epicondyle shows a bone center at about five years and at about ten or twelve years it has been separated from the rest of the epiphysis by growth of the shaft downward into the epiphysis, leaving only a shell of epiphysis over the trochlear surface, with a small ossification center. From this time onward, growth occurs by progressive ossification of the external condyle and by growth of the diaphysis downward.

"The external condyle unites to the shaft usually between sixteen and nineteen years of age, but may persist longer.

"There is an ossification center of the external epicondyle appearing at twelve to fourteen years, fusing, as a rule, with the external condyle by the sixteenth year. This is never more than a scale and is surgically unimportant.

"Growth of the trochlea is by growth of the shaft down into the epiphysis, and the lower end of the ossified shaft becomes very oblique as time goes on.

"The last epiphysis to unite is that of the internal epicondyle. It may join as early as the sixteenth to the eighteenth year, but often there is

Digitized by Google

delay, and according to Rambaud and Renault it may remain as an epiphysis through life.

"The lower epiphysis of the humerus unites to the shaft about the seventeenth year. The lower epiphysis of the humerus is made up of the external epicondyle, the capitellum and trochlea. These separate centers of ossification unite about the thirteenth year, and about the seventeenth year they join the shaft of the bone. The internal epicondyle is entirely separate from the large, general, lower humeral epiphysis." (Scudder's Treatment of Fractures.)

"The humerus is developed from a center of ossification for the diaphysis, which appears during the eighth week of fetal life, and six or seven secondary centers for the extremities which appear after birth, the epiphysis being cartilaginous. During the first year the capitellum appears. The trochlea, external and internal epicondyles appear between the tenth and twelfth years. Complete ossification and diappearance of the synchondrosis from the twentieth to the twenty-second year." (Roberts and Kelly's Fractures.)

"During the first or second year a center of ossification appears in the capitellum. Between the eighth and twelfth years this nodule enlarges, nearly or quite reaching the trochlear groove, a nodule appearing in each epicondyle, and the diaphysis sends a prolongation down into the inner portion of the trochlea.

"Between the twelfth and fifteenth years the nodule of the capitellum unites with that of its epicondyle, and after that the final point of ossification with that of the trochlea appears.

"The trochlea unites with the capitellum about the fifteenth year. Soon after there is union with the shaft." (Stimson's Fractures and Dislocations.)

"The epiphyseal centers around the elbow appear in the following order: (1) Capitellum of humerus in the first half of life; (2) head of radius during

Digitized by Google

the sixth year; (3) epitrochlea, or internal epicondyle, about the sixth year of life; (4) trochlea during the eleventh year; (5) olecranon later in the eleventh year, and (6) epicondyle in the twelfth year. This center frequently cannot be detected. (Ashhurst's Surgery.)

Observations Based on a Study of the Normal Elbow

None of the joints requires a more careful knowledge of the roentgenological appearance than the elbow. This is true particularly as we have so many centers of ossification in this joint. Others have probably fallen into the same error as we, interpreting as fracture lines and epiphyseal separations, normally developing epiphyses. It has been said that such an error should not creep in if the normal joint be compared with the appearance of the supposedly injured joint. Such an attitude is a confession of our ignorance, and therefore, is not one which is tenable.

The lower end of the humerus develops through three centers: one for the capitellum, one for the internal epicondyle, one for the trochlea, and at times, one for the external epicondyle. Although all the texts refer to the external epicondyle as appearing between the twelfth and sixteenth years, our observations have led us to believe that it is not constant as a separate epiphysis. Its presence is the exception rather than the rule. The time of appearance of these epiphyses varies roentgenologically. The factors which influence this are probably environment, diet and state of health as well as disturbances of the endocrine functions. These problems have so far not been attacked in this study.

Since the epiphyses develop through cartilage and since cartilage does not leave a shadow on the roentgenogram, the epiphyses are not apparent roentgenographically until some ossification has taken place.

The first epiphysis to appear roentgenographically is the capitellum. The earliest record of its appearance is at seventeen months. Up to the age

Digitized by Google

of five years the capitellum is the only epiphysis which is evident roentgenographically. At some time during the fifth year the epiphysis in the head of the radius may appear. This is not constant, as during the sixth year of life the shadow for this epiphysis is often absent. During the seventh year, the epiphysis for the head of the radius is constantly found.

The internal epicondyle appears in some instances at this age, but it is not constant. Here we notice a marked contrast between our findings and the statements in several well-known textbooks. Reference to the portion of the paper in which we reviewed the literature will show that the time of appearance of the internal epicondyle is given as five years of age. We have not found it prior to seven years of age. It is a curious fact that many authors have accepted and apparently incorporated the error of others in their own writings. Not only is the internal epicondyle not constantly found at seven, when we find it, but it is not always evident during the eighth, ninth and tenth years.

An appreciation of the relationship of the internal epicondyle to the shaft will be helpful in making the diagnosis of epiphyseal separation. The internal epicondyle appears close to, and almost continuous with, the internal oblique line of the shaft of the humerus. As the condyle develops it increases in size from above downward (Figs. 34 and 36).

At eight years of age we have noted a beginning olecranon and trochlea. These epiphyses are not constant at this time. Textbooks (Gray, Knox, Cunningham, Roberts and Kelly, Scudder, and Ashhurst) give the time of appearance of the trochlea as the tenth to twelfth year. Reference to Figures 34, 35 (eight years) and 36 (nine years) demonstrated the early shadows of an ossifying trochlea. During the tenth year the trochlea develops to a considerable extent (Figs. 39 and 40). We are therefore forced to conclude that the trochlea does appear as early as the eighth year and is constantly found by the tenth year except in cases of underdevelopment.

Digitized by Google

TABLE III

TIME OF APPEARANCE OF CENTERS OF OSSIFICATION IN EPIPHYSES OF LOWER END OF HUMERUS ACCORDING TO THESE OBSERVATIONS

Age	Capitellum	Internal Epicondyle	Trochlea	External Epicondyle	Ossification	Head of Radius	Olecranon
	17 mos.						
6 yrs.	Yes					½ circumference	
7 yrs.	Yes	yes				Yes	
8 yrs.	Yes	Yes (not constant)	Yes (not constant)			Yes	Yes (not constant)
9 yrs.		Yes (not constant)	Yes (not constant)			Yes	Yes
10 yrs.		Yes (not constant)	Yes (not constant)				Yes
11½ yrs.	Yes	Yes	Yes			Yes	Yes
12 yrs.	Yes	Yes	Yes		Yes in one instance	Yes	Yes

The capitellum, which is the first to appear, develops from within outward, and by the tenth year occupies the base of the shaft of the humerus from the middle of the olecranon fossa outward.

During the eleventh year of life we have noted frequently a union between the capitellum and the trochlea, but no ossification of the epiphysis and the diaphysis. This is not, however, a constant finding, as we find the trochlea and capitellum still ununited in some instances at twelve and thirteen years.

Digitized by Google

During the twelfth year of life the capitellum and trochlea have, in some cases, not only completely developed, but the epiphyseal line between them has become obliterated.

The olecranon and trochlea are the most variable epiphyses at this age. The trochlea is represented in some persons by a small shadow; in others, it has, as previously stated, become united to the shaft.

The olecranon epiphysis appears as early as the eighth year, in some instances as a small elliptical mass widely separated from the ulna. This finding is rare. Occasionally this epiphysis is manifest at nine years.

During the tenth year, there are at times two distinct shadows in the region of the olecranon epiphysis. By this time this epiphysis is constantly found.

The two shadows for the developing olecranon suggest either an irregular ossification within one epiphysis, or two separate epiphyses, one for the tip and one for the posterior portion of the olecranon. The olecranon is constantly evident and well developed during the eleventh and twelfth years.

At this time, there is some union between the epiphysis and the shaft; the ossification between the two takes place from before backward.

The thirteenth year finds the capitellum and trochlea in most instances completely developed and united; but there is a line separating the united epiphyses from the diaphysis. In some instances, this union has occurred.

The internal epicondyle has not united to the shaft at thirteen years; but the olecranon has become united by one-half its length to the shaft of the ulna.

The well-developed head of the radius is also still separated by a line from its shaft.

At fourteen years of age, we find complete development and union of the epiphyses to their respective shafts, except in the case of the internal epicondyle. In one instance, we have noted that this also has occurred.

Digitized by Google

During the fifteenth, sixteenth and seventeenth years, this condition is noted, the internal condyle alone remaining ununited at seventeen years.

All the texts refer to the external epicondyle as appearing between the twelfth and sixteenth years. Our observations have led us to believe that it is not constant as a separate epiphysis. Its presence is the exception rather than the rule.

Digitized by Google

Interpretation of Individual Roentgenograms of the Normal Elbow at Various Ages (Plates v–xviii)

Digitized by Google

PLATE V

The first epiphysis to appear is the capitellum.

Seventeen Months (Fig. 25). A small shadow is present below the shaft. The shadow is located in the plane of the anterior border of the shaft.

Five Years (Figs. 26 and 27). The capitellum is still the only epiphysis which leaves a shadow. The position is slightly posterior to the plane of the anterior border of the shaft.

The plane of the axis of the capitellum intersects that of the shaft at an angle of approximately 120°. The anterior border of the capitellum is more closely approximated to the shaft than is the posterior border.

The capitellum roughly measures ½ cm. by ½ cm.

Digitized by Google

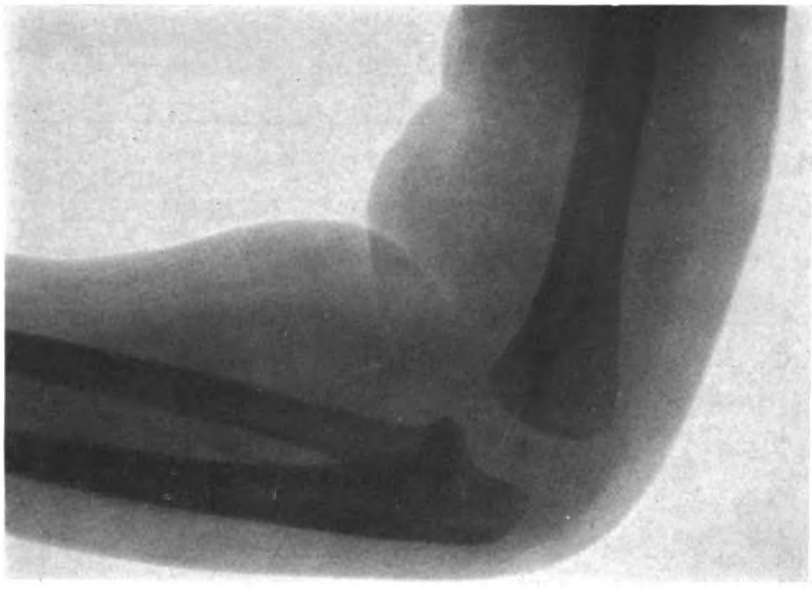


FIG. 25. SEVENTEEN MONTHS.

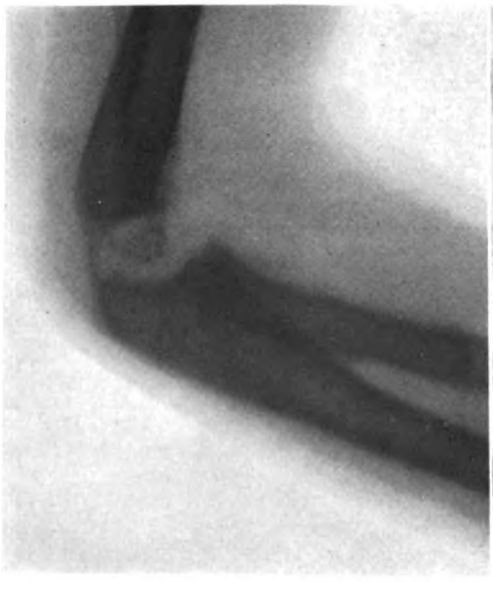


FIG. 26.

FIG. 27.

FIGS. 26 AND 27. FIVE YEARS.

Digitized by Google

PLATE VI

Five Years (Fig. 28). The capitellum is nearly 1 cm. by ¾ cm. The epiphysis for the head of the radius is evident, occupying about one-half the circumference of the proximal end of the radius.

Six Years (Fig. 29). The capitellum alone is present (measuring not more than ½ cm.) corresponding in development to that shown in Figures 26 and 27, of a five-year-old patient.

Six Years (Figs. 30 and 31). The capitellum (measuring 1½ by 1½ cm.) is closely approximated to the shaft. The head of the radius is one-half the size of the circumference of the shaft.

Summary. 1. The capitellum is the only epiphysis about the elbow which ossifies during the first five years. Ossification begins in this epiphysis during the first eighteen months.

2. The epiphysis for the head of the radius may begin to ossify during the fifth year. Ossification may be delayed, however, until the seventh year, as it is not regularly evident during the sixth year. (Refer to Figs. 28 and 29.)

Digitized by Google

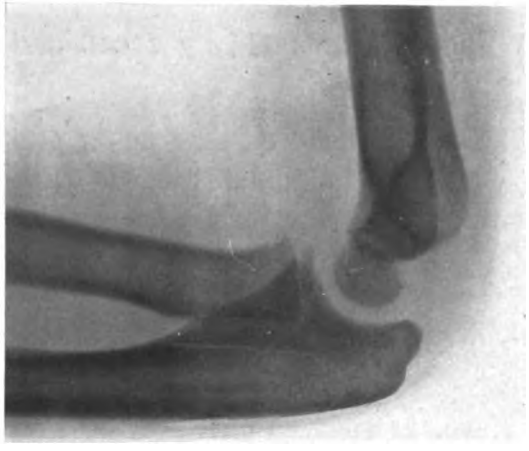


FIG. 28. FIVE YEARS.

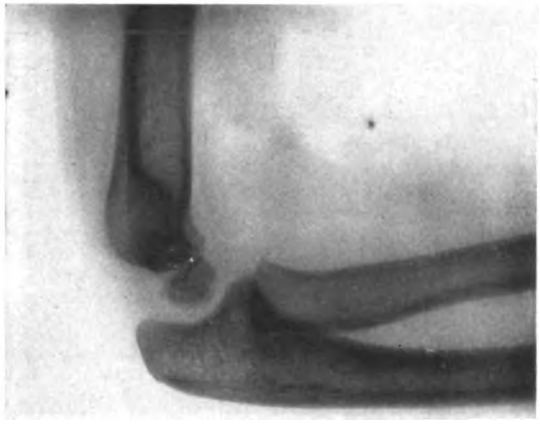
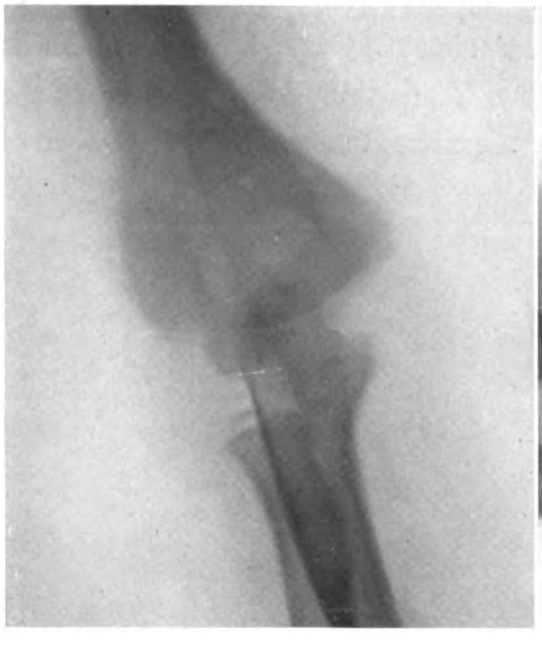
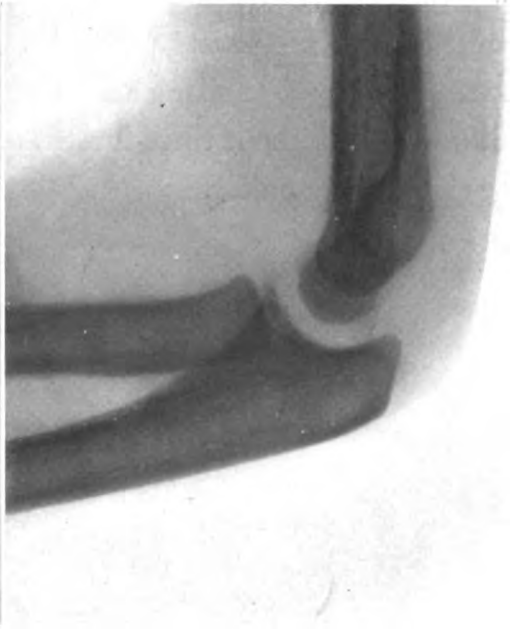


FIG. 29. SIX YEARS.





FIGS. 30 AND 31. SIX YEARS.

Digitized by Google

PLATE VII

Seven Years (Fig. 32). The capitellum measures 1½ by 1 cm. and is above the olecranon fossa.

The internal epicondyle appears as a small round shadow below and internal to the shaft. The head of the radius is one-half the size of the circumference of the shaft.

Eight Years (Figs. 33 and 34). The following centers are present: The capitellum, internal epicondyle, trochlea, head of the radius, and occasionally the olecranon.

The capitellum measures 1½ by 1 cm. It extends outward, so that its external margin is practically continuous with the external oblique line of the broad lower end of the shaft of the humerus. The internal epicondyle is about ½ by ¾ cm. and is separated by a rather marked, clear space from the internal oblique line of the broad lower end of the shaft of the humerus. The trochlea is represented by a tiny shadow internal to the capitellum and separated from it by about ½ cm. The olecranon is represented by a similar small shadow. The epiphysis of the head of the radius occupies about three-fourths of the circumference of the upper end of the shaft of the radius.

Digitized by Google

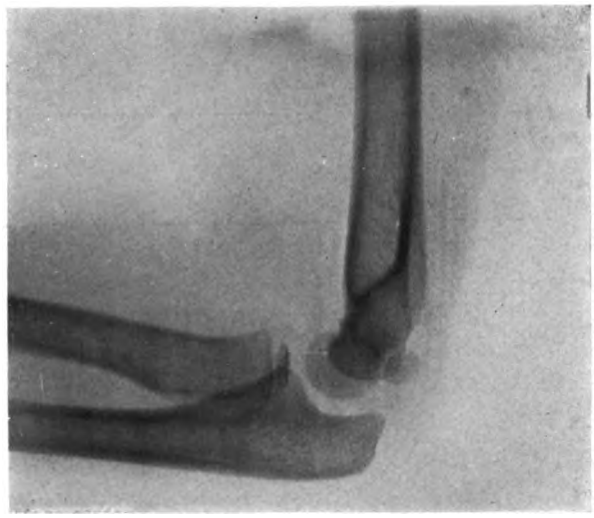
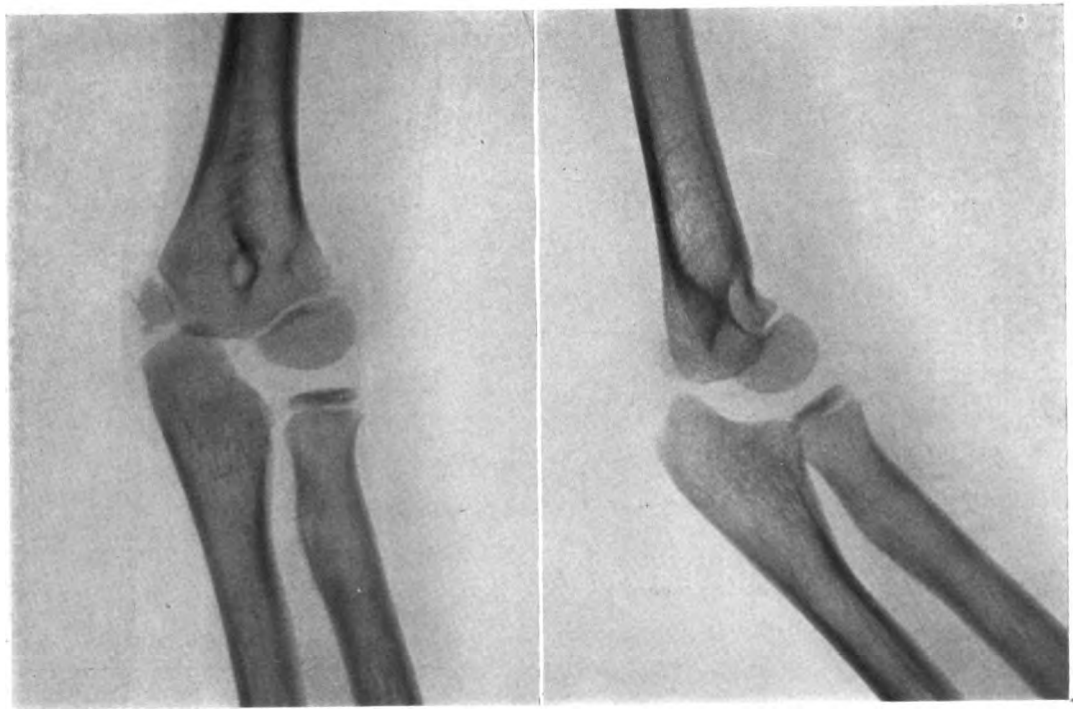


FIG. 32. SEVEN YEARS.



FIGS. 33 AND 34. EIGHT YEARS.

Digitized by Google

PLATE VIII

Eight Years (Figs. 35 and 36). The olecranon epiphysis is only occasionally sufficiently ossified at this age to leave a shadow.

In Figure 35 the appearance is practically that of the preceding one with the exception of the fact that there is no shadow for the olecranon.

In one instance, there was no shadow for the olecranon or for the trochlea. The capitellum has not extended so far out as in the previously described roentgenograms. There is no evidence of an internal epicondyle or trochlear process. The diaphysis has extended downward, particularly on the inner side.

In another patient of the same age, there is no center for the olecranon or for the trochlea. The lower end of the diaphysis of the humerus shows the same tendency to broaden out and extend downward on the inner aspect. There is no internal epicondyle.

At eight years of age, we have in some instances only one epiphysis sufficiently ossified to manifest itself, that being the capitellum. The other extreme noted for the same age shows the well-developed capitellum, internal epicondyle, head of the radius, and small shadows of an early ossifying trochlea and olecranon (Fig. 34).

Nine Years (Figs. 37 and 38). The internal epicondyle is present, the dimensions being ½ by 1 cm. Its upper limit is practically on a level with the oblique line of the shaft.

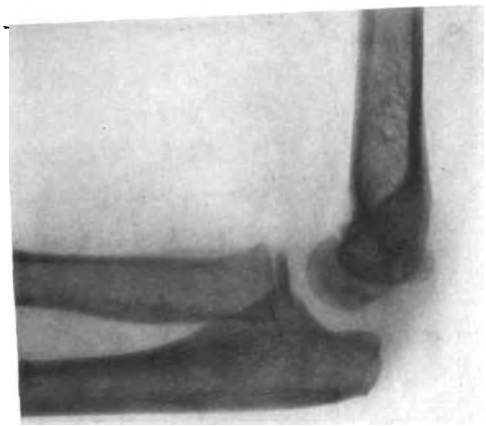
The capitellum measures 2 by 1 cm. in its greatest long axis. Its growth is more marked to the radial side. The capitellum extends fully ½ cm. anterior to the plane of the long axis of the shaft of the humerus.

The trochlea is represented by two shadows ¾ by ½ cm.

There is no evidence of an olecranon epiphysis.

The epiphysis of the head of the radius occupies almost the entire circumference of the upper end of the shaft. The epiphysis for the head of the radius seems divided as though there were a loss in continuity. Probably this is indicative of an irregular ossification going on in this epiphysis. The capitellum extends fully ½ cm. anterior to the plane of the long axis of the shaft of the humerus.

Digitized by Google



FIGS. 35 AND 36. EIGHT YEARS.

FIGS. 37 AND 38. NINE YEARS.

Digitized by Google

PLATE IX

Nine Years (Fig. 39). The internal epicondyle is present. The capitellum is developing as in previous descriptions. The epiphysis of the olecranon is evident as a small elliptical shadow. The head of the radius is as usual. Two small shadows suggestive of beginning trochlear process are visible.

Summary. A shadow of the olecranon epiphysis is not present in some cases at nine years; in others, it has ossified sufficiently to leave a shadow ¼ cm. in diameter.

The trochlea in some is not present; in others there are two shadows present, ¾ by ½ cm.

Ten Years (Figs. 40 and 41). At ten years the capitellum is well developed, occupying that portion of the lower end of the shaft corresponding to the middle of the olecranon outward. The trochlea has not yet united with the capitellum nor have either of the epiphyses united with the shaft.

The internal epicondyle is well developed but there is still a marked epiphyseal line.

The olecranon is widely separated from the shaft of the ulna.

At times the trochlea, olecranon and internal condyle have not begun to ossify at ten years.

Digitized by Google

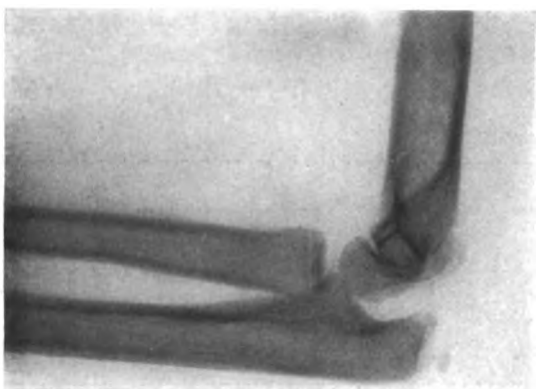


FIG. 39. NINE YEARS.

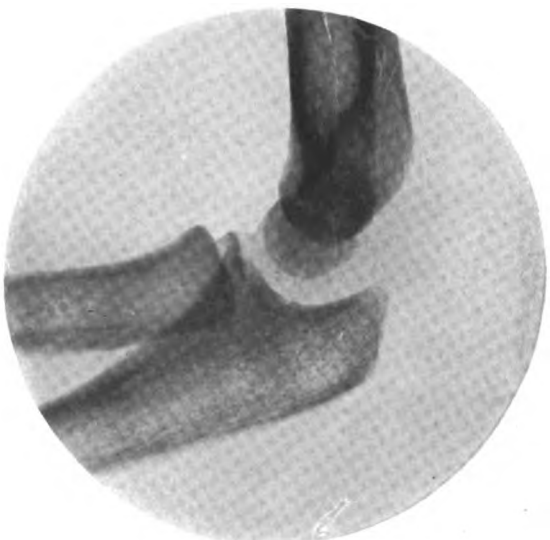


FIG. 40. TEN YEARS.

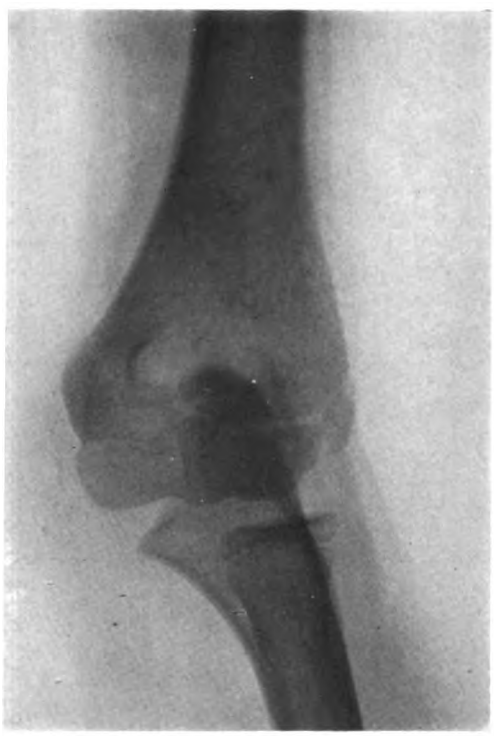


FIG. 41. TEN YEARS.

FIG. 42. ELEVEN YEARS, SIX MONTHS.

Digitized by Google

PLATE X

Eleven Years (Figs. 43, 44, 45 and 46). There is almost complete ossification of the capitellum and trochlea, and union between these two epiphyses at this time. Occasionally after this age an incompletely ossified trochlea is noted, but this is the exception rather than the rule. Union between the epiphyses and the diaphysis does not take place this early, though the line of demarcation is very fine.

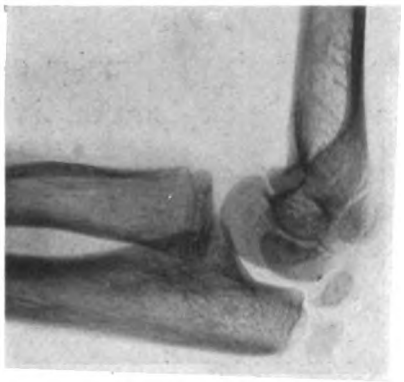
The internal epicondyle has increased in size, but it does not unite with the shaft at this time.

The external epicondyle is not usually represented by a separate epiphysis, but occasionally we have noted a separate epiphysis (Fig. 42).

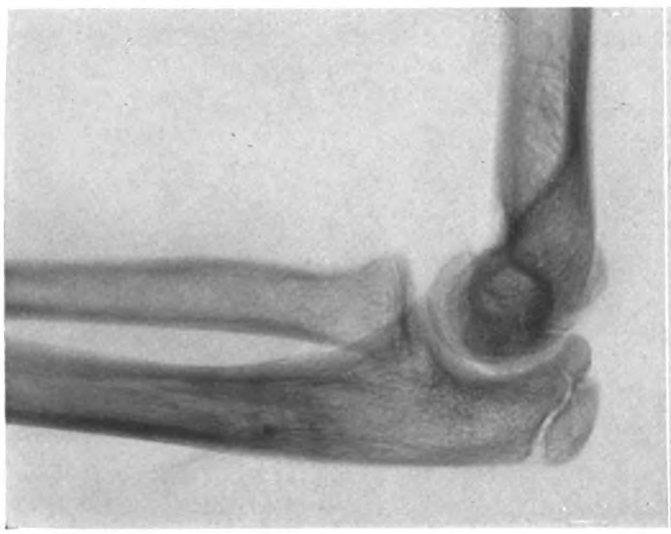
The olecranon presents an interesting picture at this time. Ossification proceeds irregularly; at times there seem to be two separate epiphyses, or this may be due to ossification within one epiphysis with two separate centers. In all instances development is greatest near the tip and progresses from before backward.

The head of the radius has completely ossified, but union with the shaft has not taken place.

Digitized by Google



FIGS. 43 AND 44. ELEVEN YEARS.



FIGS. 45 AND 46. ELEVEN YEARS.

Digitized by Google

PLATE XI

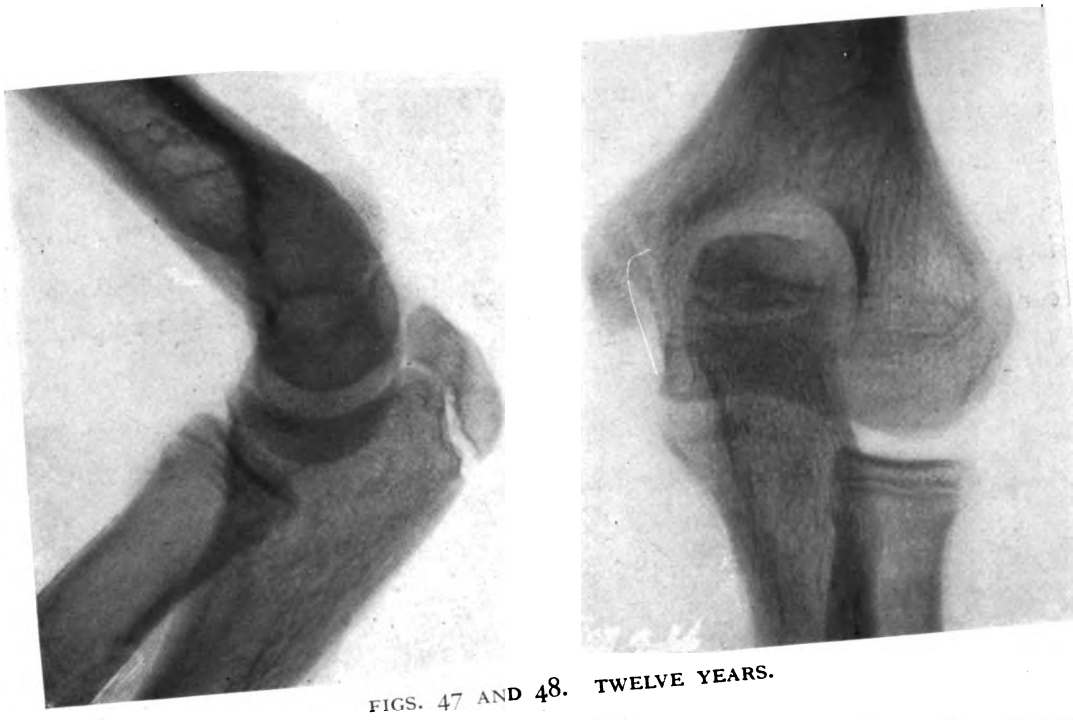
Twelve Years (Figs. 47 and 48). Complete ossification and union of the capitellum and trochlea have taken place; a persistent epiphyseal line between the shaft and the united epiphyses may be noted.

There is a persistent epiphyseal line between the internal epicondyle and the shaft. There is no evidence of an external epicondyle epiphysis. The olecranon is completely ossified, but persists in having an epiphyseal line. The head of the radius has not become united to the shaft.

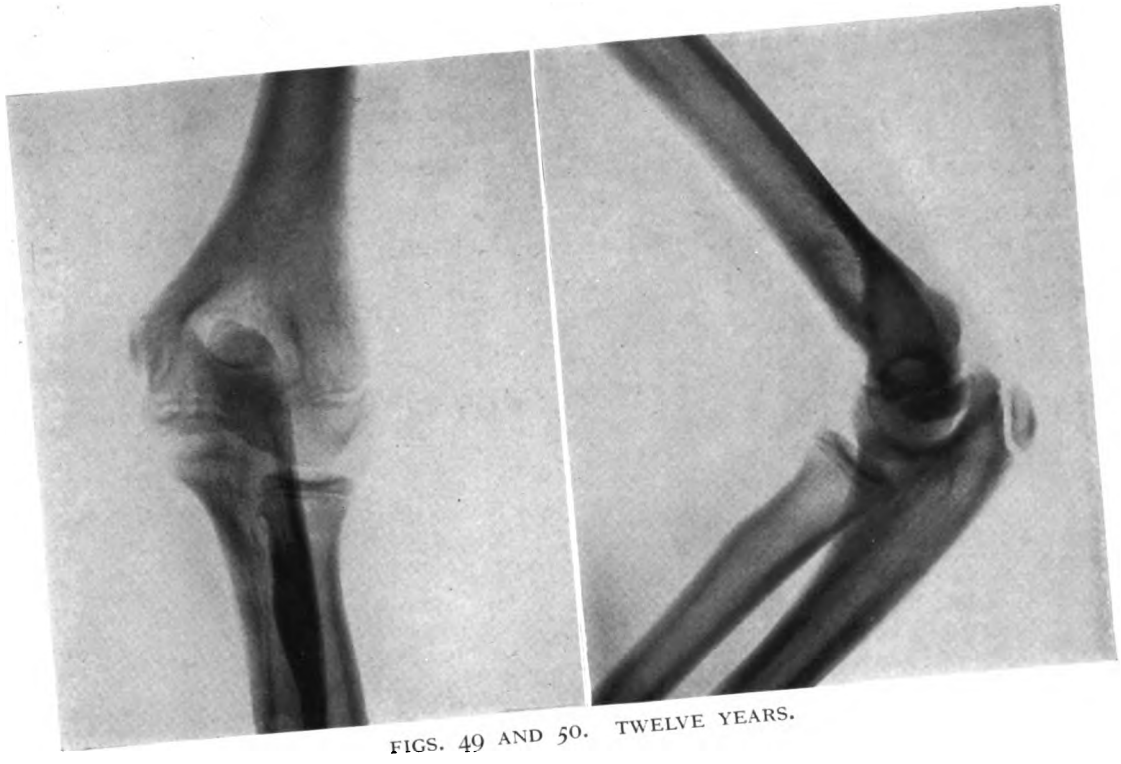
Twelve Years (Figs. 49 and 50). These roentgenograms differ from the preceding in that the olecranon is less well developed.

The internal epicondyle is about ¾ by ½ cm.; the capitellum and trochlea have united and occupy practically the entire lower aspect of the shaft. The head of the radius occupies the entire circumference of the upper end of the shaft.

Digitized by Google



FIGS. 47 AND 48. TWELVE YEARS.



FIGS. 49 AND 50. TWELVE YEARS.

Digitized by Google

PLATE XII

There is no evidence of an external epicondyle, and no evidence of an elocranon. The head of the radius covers the entire circumference of the upper end of the shaft. Figures 53 and 54 (twelve years) correspond almost entirely to Figures 51 and 52 (twelve years) except that the olecranon nodule is present, but small. There is no evidence of ossification of the epiphyseal centers to one another, nor union of the centers to the shaft.

Summary. Varying Appearance at Twelve Years. The olecranon shadow is absent in one (Fig. 51); a small shadow in one (¼ cm.), in another ¾ cm.; almost completely ossified in another. The ossification is more complete near the anterior portion of tip; there is still some separation posteriorly.

The capitellum continues to increase in size; and in some instances there is ossification to the trochlea and to the shaft.

The epiphyseal line is almost entirely obliterated in one instance.

The trochlea shows a variable stage of development from a small shadow to a completely developed epiphysis.

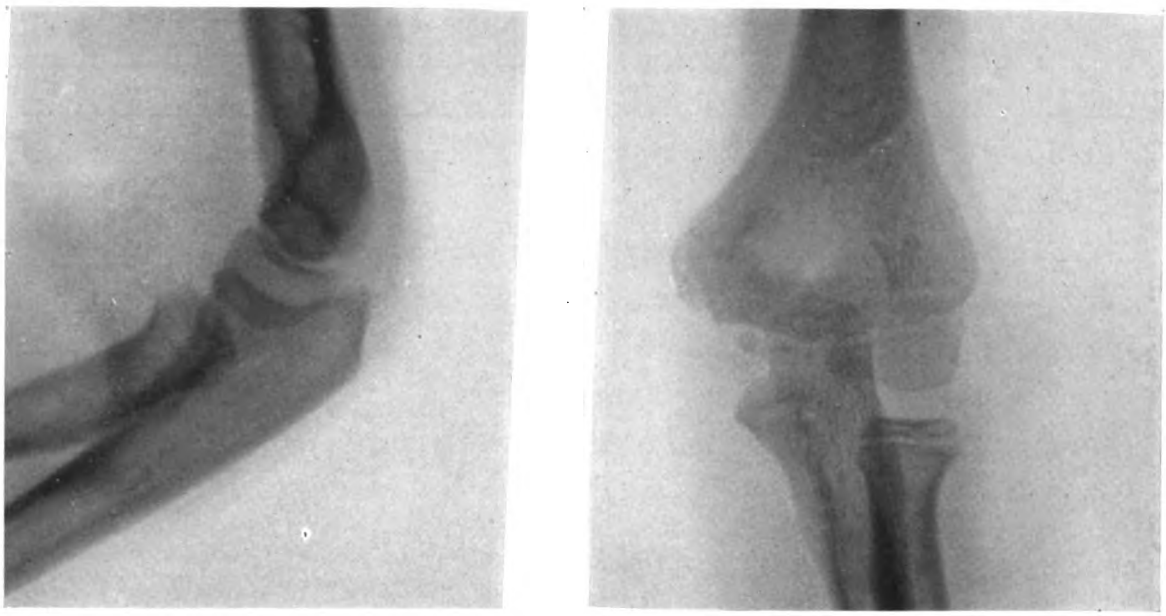
The absence of ossification within the olecranon epiphysis and the small trochlea at times are probably cases of underdevelopment.

The internal epicondyle is constantly present and increasing in size; in one instance the epiphyseal line is completely obliterated.

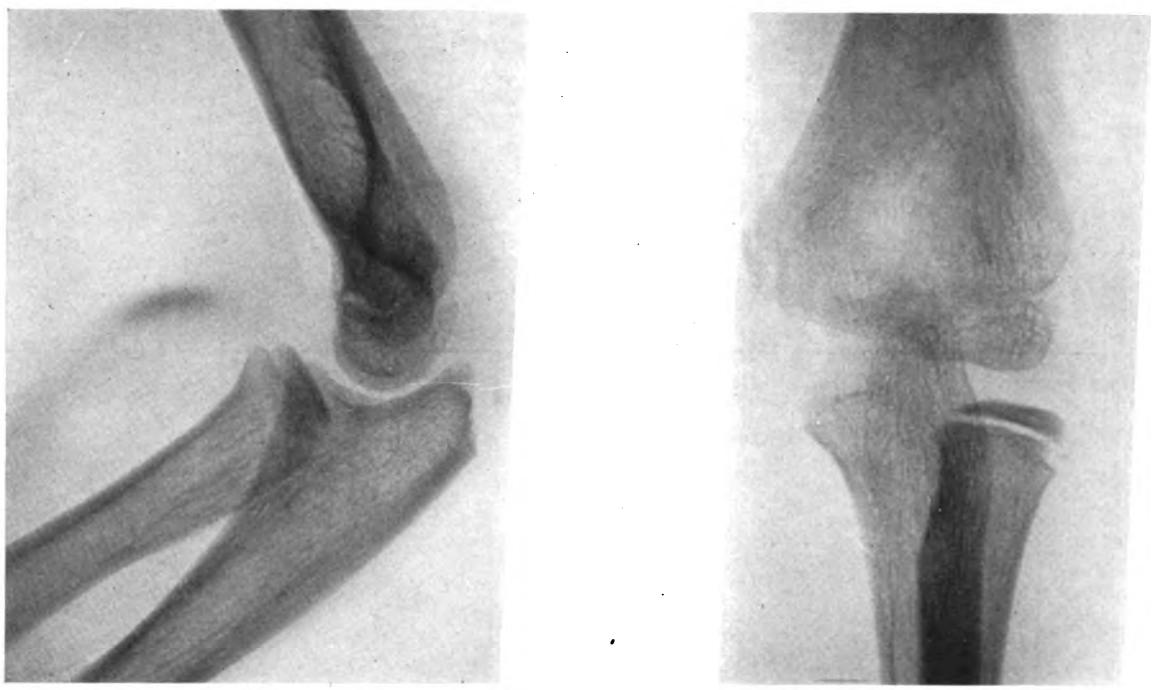
The capitellum (2½ by 1 cm.) extends from the middle of the olecranon fossa outward.

The trochlea is represented by large nodules, not yet united to the capitellum.

Digitized by Google



FIGS. 51 AND 52. TWELVE YEARS. (CASES OF UNDERDEVELOPMENT.)



FIGS. 53 AND 54. TWELVE YEARS. (CASES OF UNDERDEVELOPMENT.)

Digitized by Google

PLATE XIII

Thirteen Years (Figs. 55 and 56). The capitellum extends from the middle olecranon fossa to the level of the outer border of the oblique line of the lower end of the humerus, 2½ by 1 cm. The epiphyseal line is still well marked.

The trochlear nodule is larger than in previous years, but there is no union with the capitellum. There is still an epiphyseal line between the internal epicondyle and the shaft. The olecranon nodule is smaller than in some roentgenograms of previous years. The head of the radius occupies the entire upper end of the shaft of the radius; there is no union. (This is probably an underdeveloped child.)

Digitized by Google

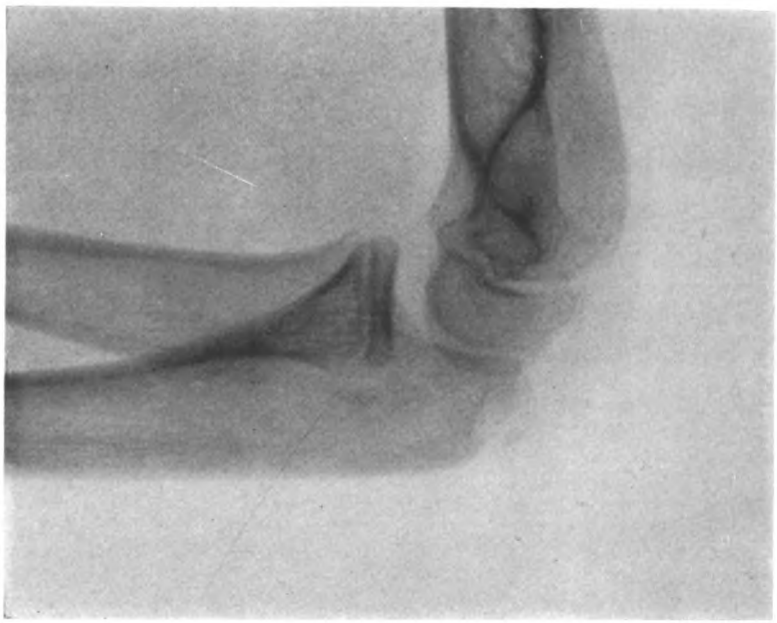


FIG. 55. THIRTEEN YEARS.

FIG. 56. THIRTEEN YEARS.

Digitized by Google

PLATE XIV

In the average case there is union of the trochlea and capitellum. There is no evidence of the epiphyseal line between the shaft and the united capitellum and trochlea. The epiphyseal line between the internal epicondyle and the shaft is still present (Fig. 57).

Thirteen Years (Figs. 57, 58, 59). There is a shadow which is evidently developing upward from the capitellum in the direction of the external epicondyle, suggesting that the external epicondyle may be an outgrowth from the capitellum in some instances.

Digitized by Google

FIGS. 57 AND 58. THIRTEEN YEARS.

FIGS. 59 AND 60. THIRTEEN YEARS.

Digitized by Google

PLATE XV

Thirteen Years (Figs. 59, 60, 61, 62, 63). The olecranon epiphysis is almost completely ossified and is united for one-half of its length to the ulna. Union is taking place from before backward.

The olecranon and head of the radius are still separate from their respective shafts.

Summary. Thirteen Years. In some cases of underdevelopment ossification within the olecranon and trochlea epiphyses has proceeded only slightly.

The average case shows almost complete ossification of the capitellum and trochlea and union of these epiphyses, and often, union of the epiphyses with the shaft.

The olecranon usually is almost completely ossified and united in part with the shaft.

The internal epicondyle is well developed and for the most part united with the shaft; when the epiphyseal line persists it is very narrow.

The head of the radius is well developed and may be united with the shaft.

Digitized by Google

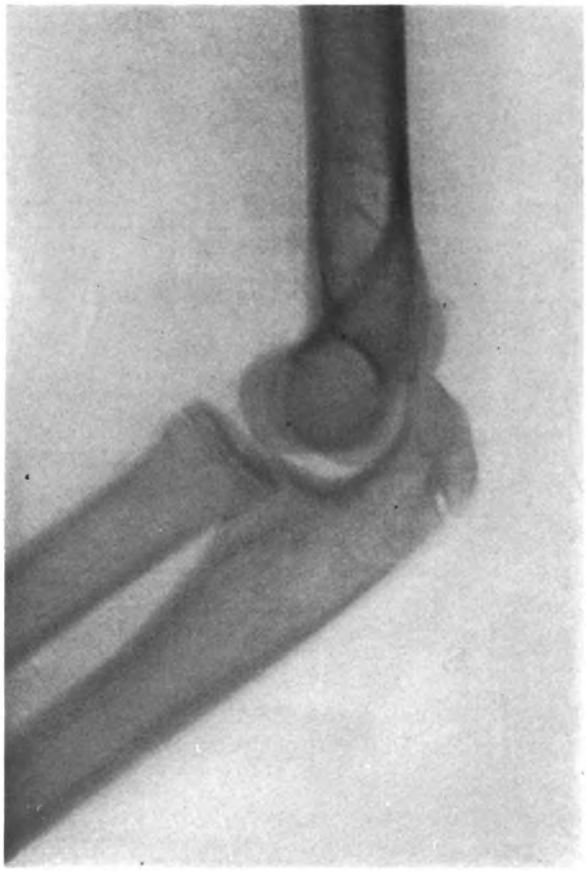
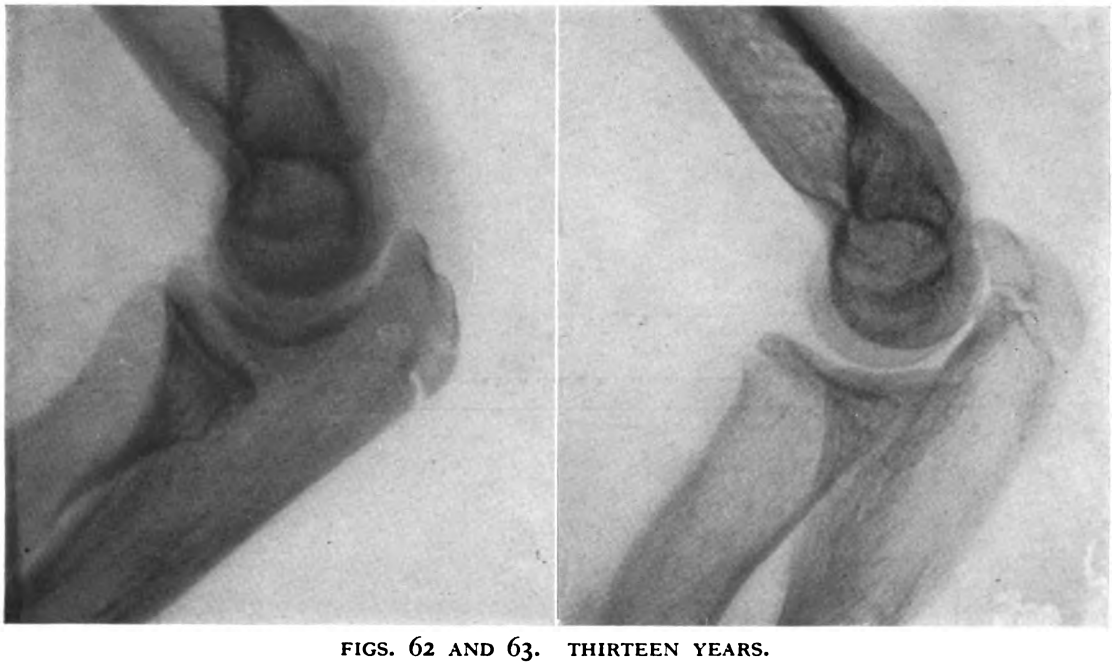


FIG. 61. THIRTEEN YEARS.



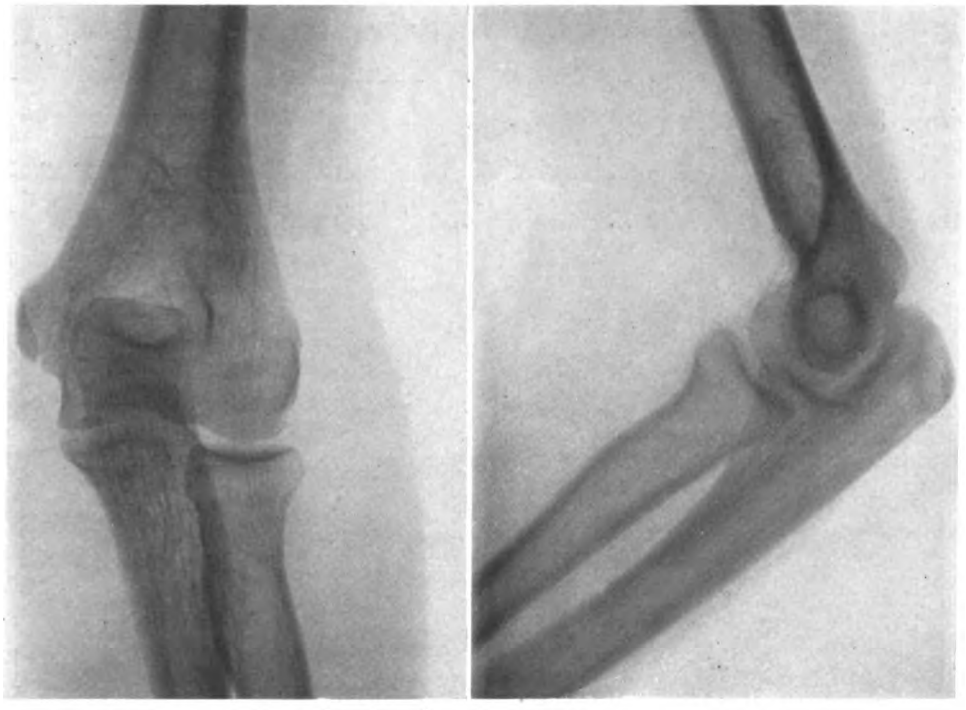
FIGS. 62 AND 63. THIRTEEN YEARS.

Digitized by Google

PLATE XVI

Fourteen Years (Figs. 64, 65, 66). These roentgenograms show complete ossification of all the epiphyses and union of all with their respective diaphyses, except the internal epicondyle, and this is noted at times.

Digitized by Google



FIGS. 64 AND 65. FOURTEEN YEARS.

FIG. 66. FOURTEEN YEARS.

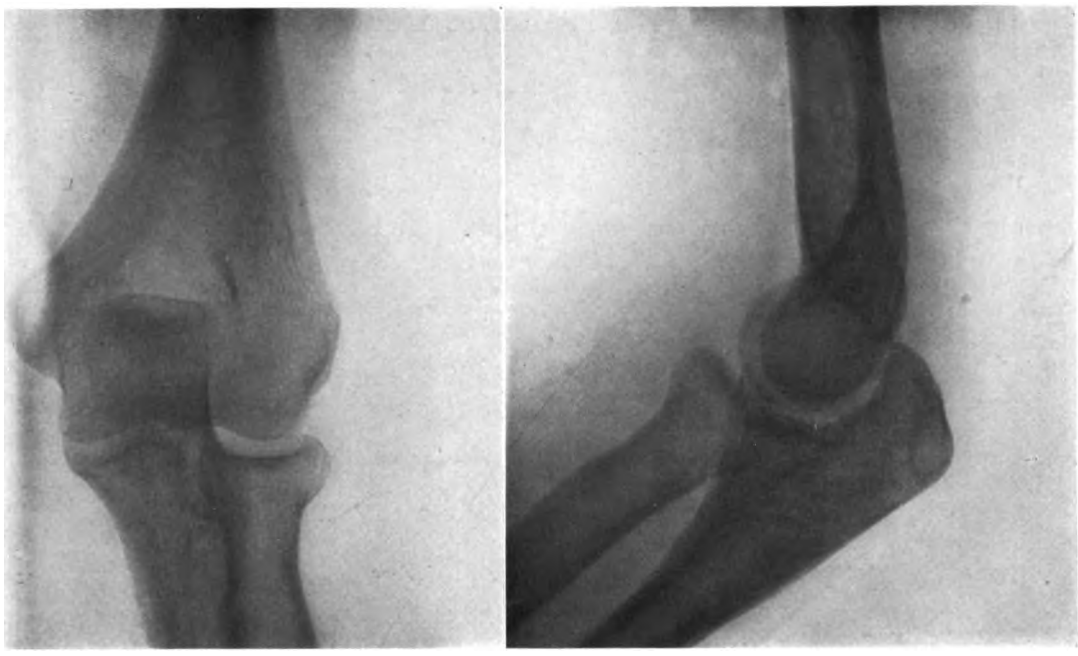
Digitized by Google

PLATE XVII

Fifteen Years (Figs. 67 and 68). There is complete ossification and union of the epiphyses with the shaft.

Figure 69 shows a persistence of all epiphyseal lines. There is a well-marked epiphysis for the external epicondyle. This is the occasional finding.

Digitized by Google



FIGS. 67 AND 68. FIFTEEN YEARS.

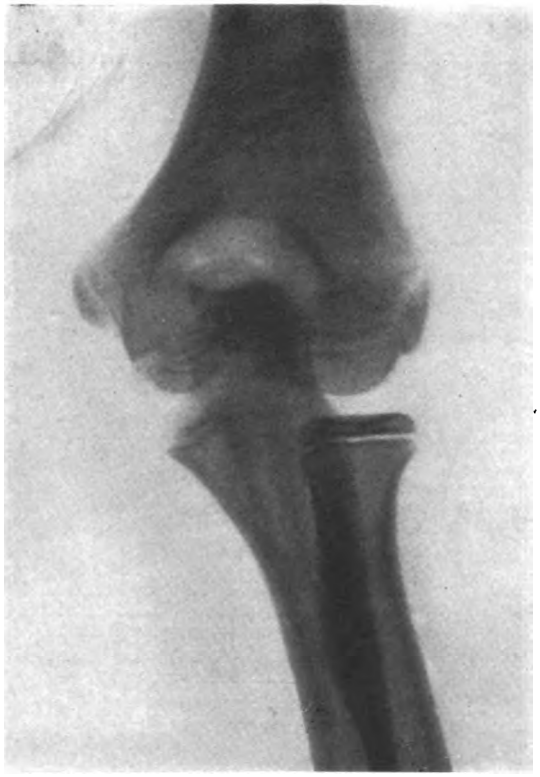


FIG. 69. FIFTEEN YEARS.

Digitized by Google

PLATE XVIII

Seventeen Years (Figs. 70, 71, 72). There is complete ossification and union of all the centers to their respective diaphyses. The internal condyle may still show a narrow epiphyseal line.

Digitized by Google

FIG. 70. SEVENTEEN YEARS.

FIGS. 71 AND 72. SEVENTEEN YEARS.

Digitized by Google

RECAPITULATION

1. The value of the proper knowledge of the roentgenographic appearance of the normally developing elbow can hardly be overestimated.

2. Many cases have been misinterpreted as fractures of one condyle or another which probably should have been interpreted as normal joints.

3. Emphasis should be laid on the proper position for taking pictures of the developing joints. It seems that the anteroposterior view of the elbow in complete extension, with the forearm in complete supination, gives the best opportunity for observing the normal relationship of the developing epiphyses.

The literature on the subject gives misleading ideas of the time at which epiphyses unite. Certainly there is no agreement among the authorities as to the period at which union occurs.

We have noted roentgenographically three centers of ossification for the epiphysis of the lower end of the humerus: the capitellum, internal epicondyle, trochlea, and occasionally the external epicondyle as a separate center. The first to appear is the capitellum; this is the only epiphysis present up to five years. The internal epicondyle appears next. It is important to note that the internal condyle appears close to, and is continuous with, the internal oblique line of the shaft of the humerus.

The head of the radius may appear at the fifth year, and at times its appearance is delayed until the seventh year. Complete ossification of this epiphysis and union with the diaphysis may occur during the thirteenth year and has been regularly noted to have united during the fourteenth year.

The olecranon epiphysis occasionally begins to ossify during the eighth year.

At the age of fourteen years, we have found complete union of the epiphyses and the shaft, with the exception of the internal epicondyle; this may remain ununited at seventeen years of age.

Digitized by Google

The developing capitellum occupies a relatively constant position. This position can be determined best by passing a plane through the middle of the long axis of the shaft of the humerus. The capitellum is anterior to this plane prior to the ninth year.

Importance to be Attached to a Study of the Normal Elbow from a Surgical Standpoint

The lively interest, which at the present time is being manifested in the subject of fractures, makes of great importance a more complete knowledge of the appearance of normal joints in the young individual.

Progress may be said to be the resultant of information plus observation. Through the application of all available information, we should arrive at a diagnosis helpful to the patient.

Errors creep in, even under the best possible conditions. The errors of omission should not creep in, and at the present time it is no longer tenable to omit such useful knowledge as the appearance of the normal joint and continue to make the error which many have made in the past, of calling normal joints, fractures or epiphyseal separations.

One of the common sources of error has been our ignorance of fundamental facts.

Careful interpretation of *x*-ray plates will enable one to arrive at a correct diagnosis and will help to avoid the error of calling normal joints, fractures, and the normal distance between the shaft and the epiphyses, epiphyseal separations.

Those who, as a result of careful histories, interpret the disability on an anatomic basis, and who also bring to their aid for the benefit of the patient the roentgen ray both before and after treatment, arrive most often at a correct diagnosis. To treat fractures satisfactorily, one must be very mindful of the relative strength of bone and ligaments when subjected to strain.

Digitized by Google

It may seem bold to state that eventually we may hope that diagnosis will often be correctly arrived at by a properly taken history and an analysis of the localization of pain and the associated functional disability. When we consider this statement a little more closely, the importance of the truth will be appreciated. Ordinarily, each muscle origin represents the fixed point from which contraction acting on the point of insertion causes the properly coordinated movement. Now, if the bone happens to be fractured between the origin and the insertion of a given group of muscles, this group is rendered inactive.

A lack of harmony results from exaggeration of the action of the opposing group.

Not only is this important in diagnosis; in treatment it is essential. Otherwise reduction will fail more often than it will succeed.

Any plea for improvement in fracture results must be based not on a preconceived system but on a clearer knowledge and attention to fundamentals.

The value of fundamental knowledge which should be more widespread and the usefulness of which, even among those who should know, we find has not been fully realized. We refer to the roentgen-ray examination particularly of joints and joint fractures in the young. The appearance of the normal epiphysis at varying ages has proved a most valuable study.

In the past, we have been impressed by the number of roentgen-ray reports suggesting seriously disturbed elbows, which on clinical examination presented no abnormality, and also by a few cases which suggested a fracture in which the roentgenogram failed to be of service to us. Another type of report which proved puzzling was the number of reported epiphyseal separations.

An analysis of the reported fractures in clinically normal joints can be easily understood after one has made a study of normal joints. The answer is simply that epiphyseal lines were mistaken for fracture lines.

Digitized by Google

How can we interpret the other two reports? Let us take those in which clinically there is an intra-articular fracture and the report is negative.

We know very well that up to a certain age certain epiphyses are not apparent in the roentgen-ray examination and hence an injury to these will not show on the plate.

It is very easy to see why epiphyseal separations have been reported because there has not been an available standard for comparison, and further, there has not been a general appreciation of the fact that the epiphyses bear a relatively constant position to the shaft.

A diagnosis of epiphyseal separation can be made roentgenographically only by a gross alteration of the normal relationship of the epiphyses to the shaft.

There are certain constant factors in the appearance of the normal elbow joint. Some of these can be expressed by a number of lines which we have utilized in our work. If anyone has described these lines before, they have not been called to my attention, nor have I seen mention of them in the literature.

I believe that, with a clear knowledge of the normal appearance of the elbow, and the relationship of the articular portion of the humerus and the ulna, we can eliminate many errors in diagnosis; and furthermore, one can definitely state from the roentgenogram that there is an existing deformity. If these things are possible, certainly they need more general adoption, because thereby a source of error will have been corrected.

The position of the capitellum is most important.

With the elbow flexed to a right angle, a lateral view of the elbow shows the capitellum occupying the sigmoid cavity. In early life, there seems to be a wide separation between the articular surface of the capitellum and the great sigmoid cavity, but with growth the capitellum occupies the entire cavity and is closely approximated to the sigmoid cavity (Figs. 73 and 74).

Digitized by Google

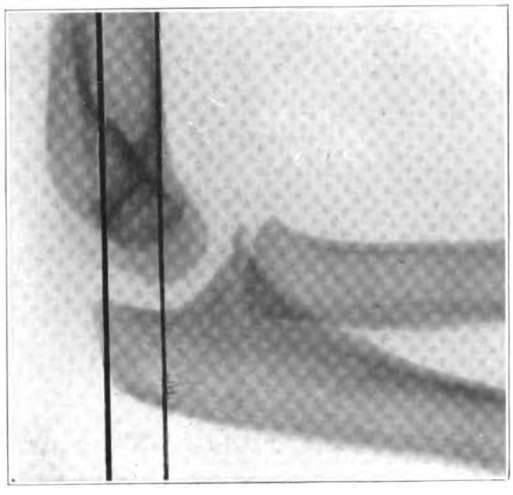


FIG. 73.

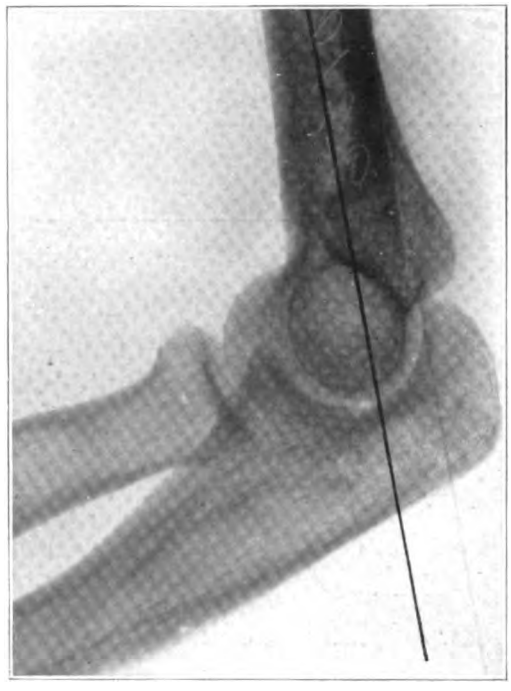


FIG. 74.

A plane passed through the middle of the long axis of the shaft of the humerus, prior to about the ninth year, passes behind the posterior border of the capitellum; after this period the plane bisecting the shaft of the humerus has approximately two-thirds of the lower epiphyses anterior to it (Figs. 73 and 74).

The plane of the anterior limit of the shaft of the humerus shows at least one-half of the capitellum anterior to it (Figs. 73 and 74).

A plane at right angles to the base of the capitellum and bisecting it intersects the plane through the middle of the long axis of the shaft at an angle of about 130° (Fig. 75).

When the forearm is extended on the arm and supinated, a plane passed through the middle of the long axis of the humerus is intersected

Digitized by Google

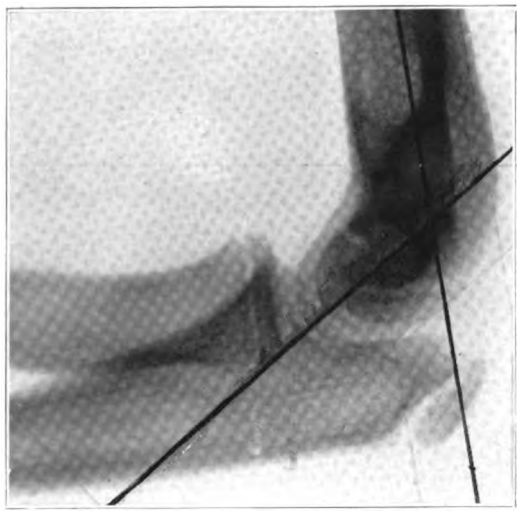


FIG. 75.

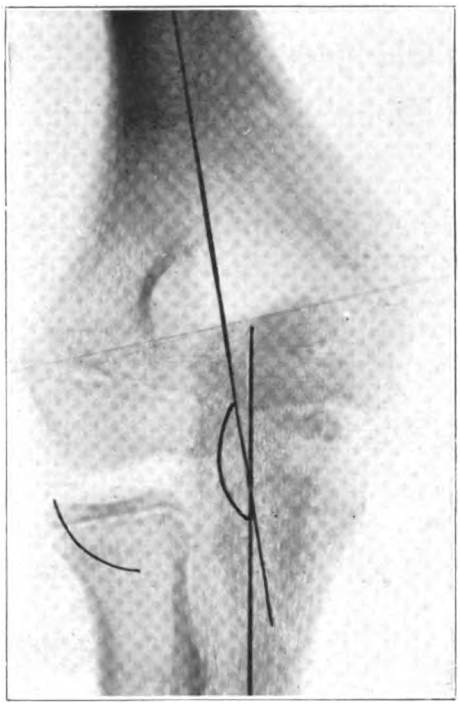


FIG. 76.

by a plane through the middle of the long axis of the ulna at an angle of approximately 170° (Fig. 76).

The olecranon occupies the entire olecranon fossa (Fig. 77).

An attempt will be made to show by an illustrative case the value of a knowledge of the exact appearance of normal joints, in order to state definitely from the picture that an epiphyseal separation exists.

CASE 1. Male, aged thirteen years, while playing, fell backward and struck his right elbow against a brick curb. He suffered considerable pain. Examination at the clinic, by Dr. I. M. Gage, revealed considerable swelling over the internal condyle, with pain on palpation. Crepitus was elicited on movement of the elbow. The roentgenogram (Fig. 78B) shows the epiphysis of the internal epicondyle widely separated from the shaft and on a much lower level than the internal oblique line of the shaft. The elbow was flexed and bandaged in the usual hyperflexed position. A picture of this position shows a restoration of the normal position of the internal epicondyle to the shaft (Fig. 78A).

Digitized by Google

To illustrate the point that roentgenograms fail us in diagnosis of intra-articular fractures, the following cases may be cited briefly.

CASE II. Male, aged eight years, presented the typical deformity of a backward dislocation of the elbow. This is all that was demonstrated by the roentgenogram. Under anesthesia the reduction was easily accomplished, but we were then able to palpate a loose body in the region of the internal epicondyle. The internal epicondyle was evidently not sufficiently ossified to leave a shadow.

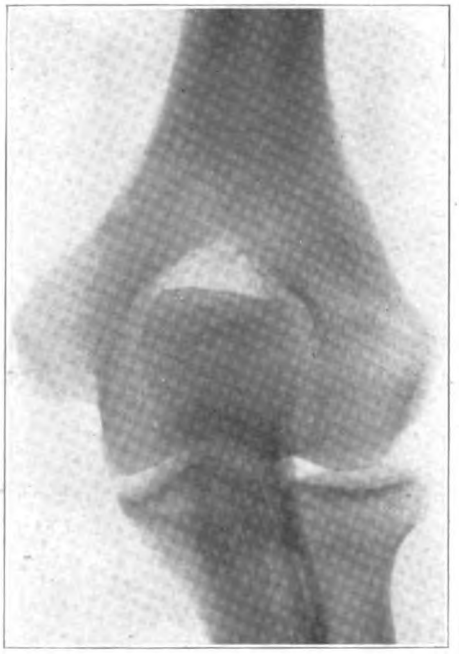


FIG. 77.

The value of the lines which have been described may best be illustrated by the presentation of a few cases in which the results were not good.

When vicious union has resulted and when the patient presents a cubitus varus, the capitellum does not occupy the sigmoid cavity, but is on a lower level and its shadow is overlapped by that of the olecranon in part (Figs. 79A, 80A and 81A). When a perfect result has been obtained, it is found that the articular surface of the humerus lies in its normal bed.

Digitized by Google

From an analysis of a group of unselected cases from our clinic and from my private records, several points are apparent.

Many reported cases of epiphyseal separation are manifestly normal joints. Many cases are referred to the roentgenologist with clinical evidence pointing to fracture, and negative reports have been returned.

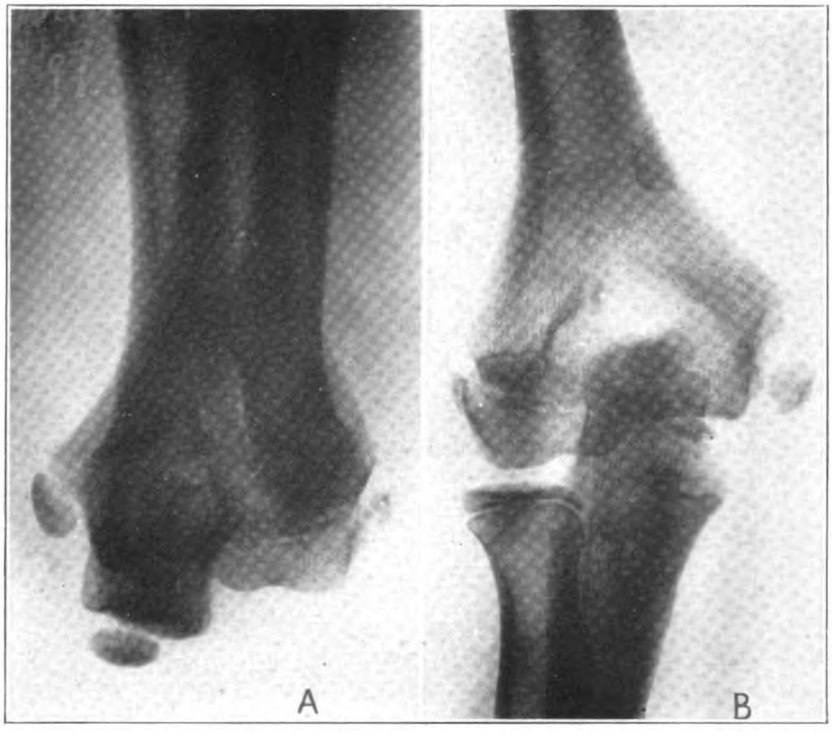


FIG. 78.

These two sources of errors uggest three things which are necessary in the treatment of fractures: a clear knowledge of the normal on the part of the roentgenologist; a more careful examination of the patient, to eliminate unnecessary work, and last, a closer cooperation between the roentgenologist and the surgeon, which will prove helpful to all.

The roentgenologist who utilizes the lines suggested here will help the surgeon to avoid many disabling deformities.

Digitized by Google

DIVISION OF CASES

We may divide the cases of elbow injuries into those in which examinations, clinical and roentgenological, have been negative; cases in which there has been a separation of the epiphyses; and cases in which there has been a fracture.

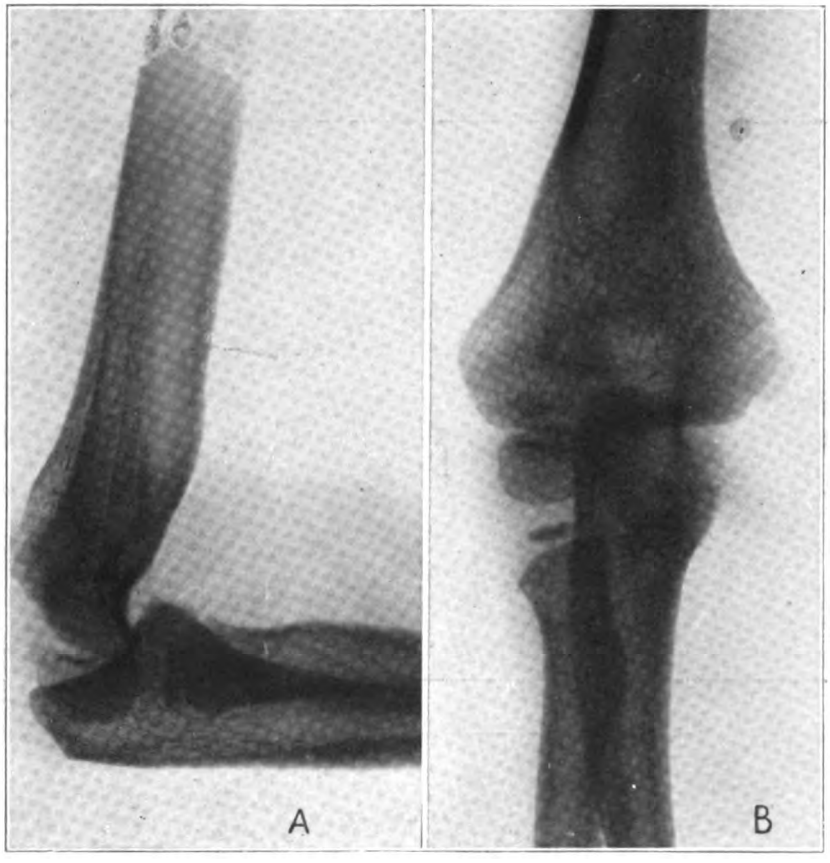


FIG. 79.

The fracture cases then subdivide themselves into two classes: those which come under observation immediately and those which are not seen for several hours.

In an attempt to follow up cases, about seventy-five patients were written to, with a request that they present themselves for examination.

Digitized by Google

From those who returned we have obtained the material for this study. The information thus obtained has enabled us to note whether there was a perfect functional result or how much disability existed, and to gather information relative to the roentgen-ray appearance of the fractured bone.

A small group of patients with deformity and disability presented themselves for examination. These cases, while the condition is humiliating, give more real beneficial information than the larger group with good results. It was from the small group which presented disability and deformity that we were made to realize the value of the roentgen ray in making a prognosis.

In every case in which we found an existing deformity, several things became apparent when the history was referred to. In brief, the facts are

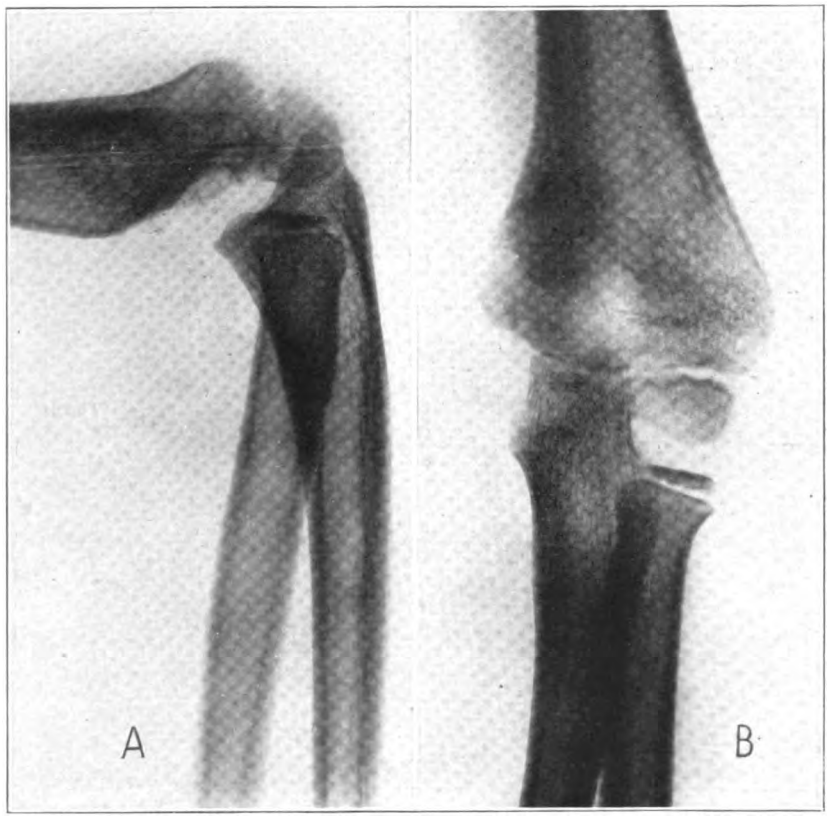


FIG. 80.

Digitized by Google

these: The patient usually presented himself for treatment several hours after the injury, during which time swelling had appeared, making it impossible to maintain the hyperflexed position.

Citation of 2 cases, with remarks, will serve to prove my point.

Case III. Male, aged four years, fell from a wagon two days before examination, March 12, 1918.

Examination. The arm hung by his side. There was marked cubitus varus, swelling about the elbow, pain over both condyles, and loss of flexion and extension.

Treatment. Under anesthesia, the impaction was broken up, but we were unable to put the elbow in hyperflexion, as this position caused an obliteration of the radial pulse.

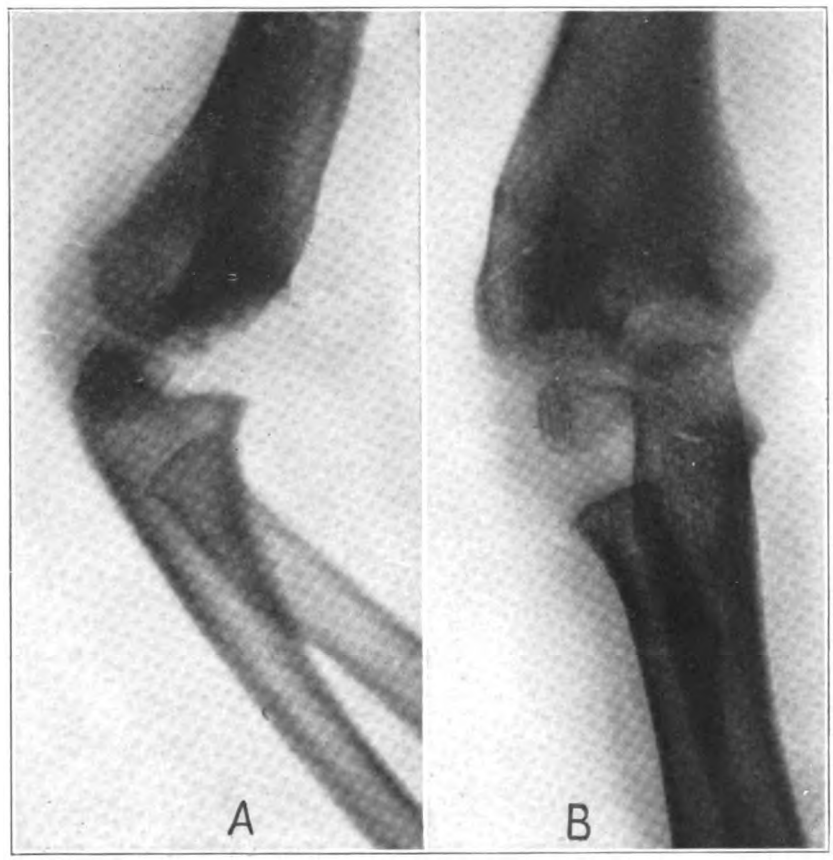


Fig. 81.

Digitized by Google

Anterior and posterior plaster splints were applied, the right angle position being used. The roentgen-ray report prior to the dressing was: Supracondyloid fracture, backward displacement of the lower fragment.

Subsequent Course. In following up this case, we found, one year later, that there was a loss of the carrying angle, cubitus varus and limitation of flexion and extension.

April 14, 1919. A cuneiform osteotomy was performed.

October 30, 1920. Examination revealed perfect flexion and extension of the elbow; no limitation of pronation and supination, and a slightly diminished carrying angle.

CASE IV. On June 13, 1918, patient had fallen from a porch the day before; had been treated in the emergency clinic at the Touro Infirmary at once with a diagnosis of supracondyloid fracture. No anesthetic was given. The dressing did not include the hand. When I saw the child, the hand and forearm were very much swollen. The hand of the injured arm was much colder than the opposite hand.

Treatment. Under ether anesthesia, an attempt was made to reduce the deformity. It was impossible to utilize the position of hyperflexion, because of obliteration of the radial pulse; therefore anterior and posterior molded plaster splints were used.

Subsequent Course. Examination, April 22, 1919, revealed a loss of carrying angle and slight cubitus varus. The forearm could be flexed to the normal limit and extended completely.

At examination, November 11, 1920, the same notes were made as at the previous examination. The roentgenogram taken November 11, 1920, revealed a vicious union of an old fracture of the humerus. The lower portion was united to the shaft in a plane oblique to that of the long axis of the shaft.

The capitellum was overlapped by the shadow of the olecranon and sigmoid cavity, instead of occupying the cavity.

A plane passed through the anterior aspect of the long axis of the humerus passed anterior to the plane of the capitellum, showing that the capitellum was displaced backward.

The plane passed through the middle of the long axis of the shaft was anterior to the capitellum, instead of the capitellum's being either entirely in front of this plane or two-thirds of its body anterior to this plane (Fig. 79A and B).

CASE V. Male, aged seven years, came under observation in the clinic, May 31, 1919, the day following the accident. Examination made by Dr. P. G. Lacroix revealed swelling of the forearm, cubitus varus, and pain over the lower end of the humerus. No record was made of the after-care in this case. The child reported to the clinic at my request for examination. I found marked cubitus varus—slight limitation of flexion; no loss of the normal range of extension, and no limitation of pronation and supination. The roentgenogram in this case presented the same important findings as were noted in the previous case (Fig. 80A and B).

Digitized by Google

CASE VI. About five weeks before, patient fell on her outstretched hand. When seen by her local physician, he told the parents that there was so much swelling that he could do nothing for her. August 28, 1920, I examined her and found marked cubitus varus with internal rotation of the arm. There was limitation of flexion and extension of the elbow.

Diagnosis. Vicious union, supracondyloid fracture of the humerus was diagnosed (Fig. 81A and B).

Operation. Under ether anesthesia (Dr. Rives, anesthetist) an external lateral incision was made, beginning about the middle third of the arm, and extending down to about the level of the head of the radius. The brachialis anticus muscle was retracted inward, the radial nerve was exposed and retracted inward, as well as the supinator longus muscle. The periosteum was incised and retracted. The brachialis anticus was retracted from the humerus, and an anterior cuneiform osteotomy was performed. The divided ends of the humerus were drilled and a kangaroo tendon suture was introduced, merely for temporary fixation. When the elbow was extended, I noticed that the carrying angle had been restored, and complete flexion of the elbow was now possible. A few interrupted sutures were introduced and the arm placed in hyperflexion. The wound healed by primary intention.

Subsequent Course. The patient left the hospital, September 7, 1920, at which time she could extend the elbow well beyond a right angle.

At the time the last note was made on this case, October 30, 1920, the patient could completely extend the elbow. She carried the arm in a position of internal rotation and pronation of the forearm. If the forearm was supinated and held in this position the carrying angle was restored, showing that there was a relaxation of the external lateral ligament and that the internal rotators were more active than the external rotators. Roentgenograms (Fig. 81A and B) showed the same points as the preceding pictures: overlapping of capitellum by olecranon shadow and backward displacement of capitellum.

COMMENT

CASE VI showed such a marked deformity that an effort was made to overcome it by operation. Before undertaking the operation, the case was studied in the light of our normal roentgenograms. It is easy to understand the limitation of extension as we will note the obliquity backward of the distal end of the humerus in this and other cases with similar deformities. The olecranon meets an obstruction before extension is accomplished, and it no longer can reach the olecranon fossa, but is stopped by the lower end of the humerus. Flexion is impossible because the coronoid probably strikes against

Digitized by Google

the lower end of the humerus before it can reach the coronoid fossa. The problem to be solved, therefore, is a reconstruction of the normal axis of the lower fragment, which means that it must be displaced forward. It seems logical, therefore, that if a cuneiform section of the humerus is removed anteriorly, this will then allow the lower fragment to be flexed or molded into position. This brings the capitellum forward, and it will allow the olecranon to reach the olecranon fossa, as shown by the accompanying illustrations.

In order to accomplish this with the least damage to the periarticular structures, one had best follow the suggestions of James Thompson of Galveston, Texas, in his monograph relative to the approach to long bones. Briefly, they may be stated thus: Deep wounds should be avoided, when the shallow ones will suffice. All nerve supply should be preserved. Unnecessary injury to muscle should be avoided, the work being done between muscles rather after sectioning them. When section is necessary it should be made as far from the nerve supply as possible. The blood supply should be preserved.

In approaching the elbow in this case and in similar cases, these principles were adhered to as nearly as possible.

The procedure adopted was briefly this: An external lateral incision was made, beginning about 2 inches above the elbow, and extending down the forearm a like distance. The brachialis anticus was exposed and the radial nerve was seen prior to its passage through the supinator longus. The supinator was retracted to the inner side of the wound. The periosteum was incised and retracted. It is important not to interfere with the epiphyses. This can be done by making the section above the epiphyseal line, and further by operating from before backward with the muscles well retracted forward. There is no danger of injuring any of the important vessels about the elbow.

CASE VII. Female, aged six years, was admitted, September 11, 1917, with a supracondyloid fracture of the humerus. She had fallen from a porch. Several hours after the

Digitized by Google

accident she was brought to the hospital. The arm was hanging by the side, abducted at the elbow more than normal. The entire arm was swollen. Under ether anesthesia, a complete supracondyloid fracture was found. Because of the great amount of swelling, it was impossible to maintain hyperflexion. A Jones elbow extension splint was tried, but the one at hand was too large, therefore anterior and posterior plaster splints were applied.

September 12th. The dressing had to be removed because of swelling. A roentgenogram showed T fracture above both condyles with some lateral displacement.

September 20th. There was less swelling of the arm and forearm and less pain. The dressing was changed and the degree of extension increased.

September 27th. The arm was placed in complete extension, the elbow was manipulated, and hyperflexion of the elbow was obtained.

A roentgenogram revealed an old supracondyloid fracture of the humerus and union with deformity.

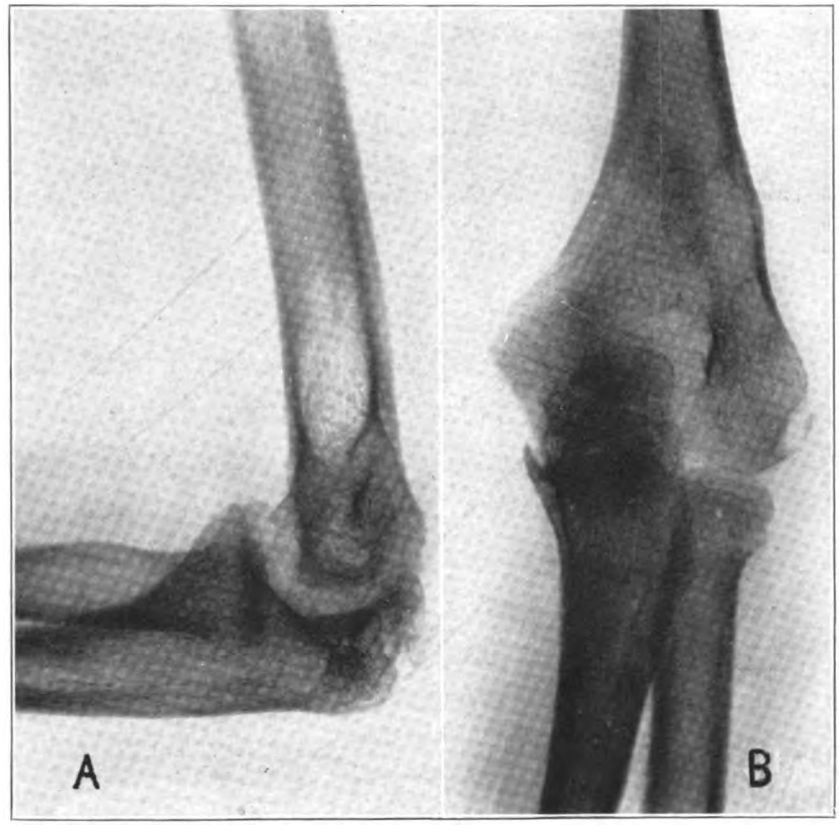


FIG. 82.

Digitized by Google

December 29, 1917. The patient was able to extend the arm to 160° and to flex it to about 45°.

October 30, 1920. The child came to the clinic in answer to my request. Examination at this time revealed complete extension of the elbow and perfect flexion, no limitation of pronation and supination, and a normal carrying angle. The roentgenogram showed a normal elbow, so far as the lines were concerned, but a premature ossification within the epiphyses of the lower end of the humerus (Fig. 82A and B; Figs. 83 and 84).

CASE VIII. Male, aged fourteen, was examined at the clinic, April 30, 1912. (The exact data regarding how the accident happened are not recorded.) There was evidence of fracture of the lower end of the humerus. The roentgenogram (Fig. 85) demonstrates the exact nature

FIG. 83.

Digitized by Google

of the injury, there being a comminuted fracture of the lower end of the humerus involving both condyles and the olecranon process of the ulna.[1]

The usual treatment was followed, and at the end of four weeks he left the city and I have not seen him since.

Dr. Maner of Bay St. Louis, Miss., wrote me a letter some time ago and informed me that the boy was able to row and swim with ease.

FIG. 84.

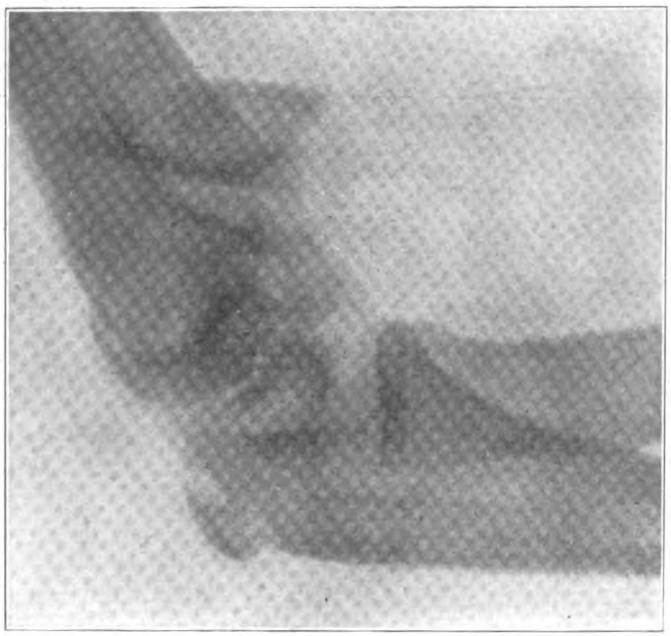


FIG. 85.

[1] At present we know that the ulna was not fractured, but the normal epiphyseal line of the unossified olecranon was interpreted as a fracture.

Digitized by Google

CASE IX. Male, admitted, May 10, 1919; five days before, while on board a ship, fell and injured his elbow. The physician on board considered the injury "a severe sprain" and did nothing except put a bandage on.

Examination. When the patient came under observation five days later (May 10th) there was marked swelling and backward displacement of the elbow, and the forearm was pronated. The forearm extended almost completely; the carrying angle was lost and the hand was swollen.

Operation. Under ether anesthesia, an attempt was made to reduce the deformity. Hyperflexion could not be maintained because of the great swelling. Right angle plaster molded splints were applied.

Roentgen Examination. The roentgenograms made before and after this attempt are shown in Figures 86A and B, and 87A. Subsequent attempts to reduce the deformity had to be made after the swelling had subsided. The final roentgenogram shows the result.

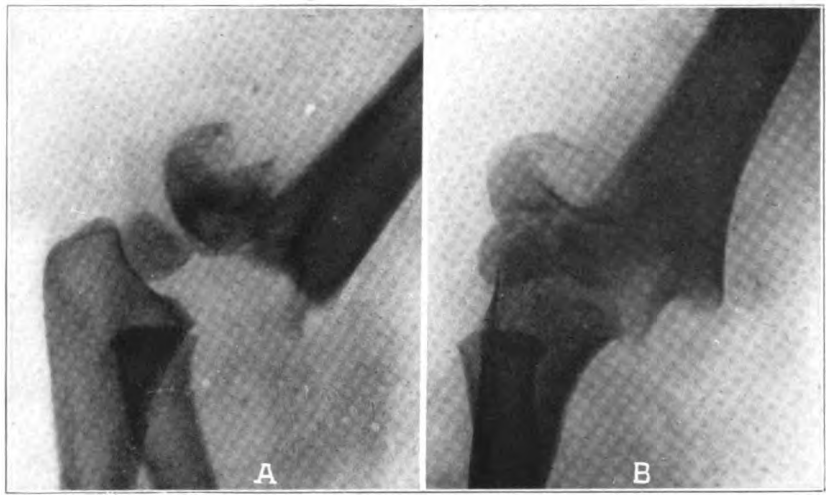


FIG. 86.

December 23, 1919. Complete extension was possible and flexion to 45°. Pronation and supination were normal. Roentgen-ray report at this time states: "Perfect union. No evidence of previous fracture except excess of callus on lower anterior aspect of humerus" (Fig. 87B).

MISINTERPRETATION OF FRACTURES

As a result of my recent study of normal joints in the young I have been interested to note how valuable the information really is when I consider the cases that have previously been reported as having epiphyseal separations.

Digitized by Google

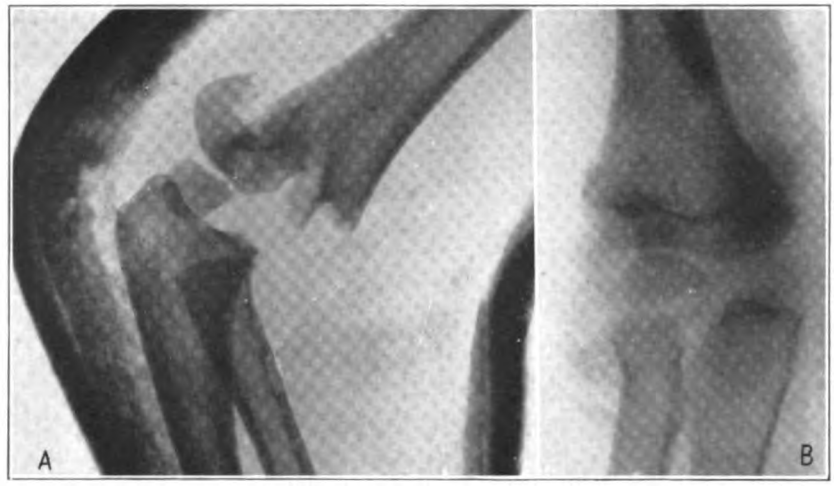


FIG. 87.

FIG. 88.

Digitized by Google

Citation of a few cases with illustrations will prove the point. Supracondyloid fractures have in the past been misinterpreted by roentgenologists as epiphyseal separations.

CASE X. Female, aged four years, fell from a small wagon and struck her elbow. Pain in the elbow and loss of function are noted on the history card. Roentgenogram: Epiphyseal separation of lower end of humerus. Position good.

The true interpretation in the light of our present knowledge is that there was in this case a supracondyloid fracture—incomplete in the transverse axis of the humerus (Fig. 88).

Under ether anesthesia, the examination was completed. There was no limitation of extension, the carrying angle was not lost, but slightly diminished. The head of the radius rotated with the shaft of the radius.

The same error in roentgen-ray interpretation was made in another patient, aged five years: "Epiphyseal separation of the lower end of the humerus, some slight dislocation of the condyle" (Fig. 89). These mistakes could not have occurred if we had known that the internal condyle does not

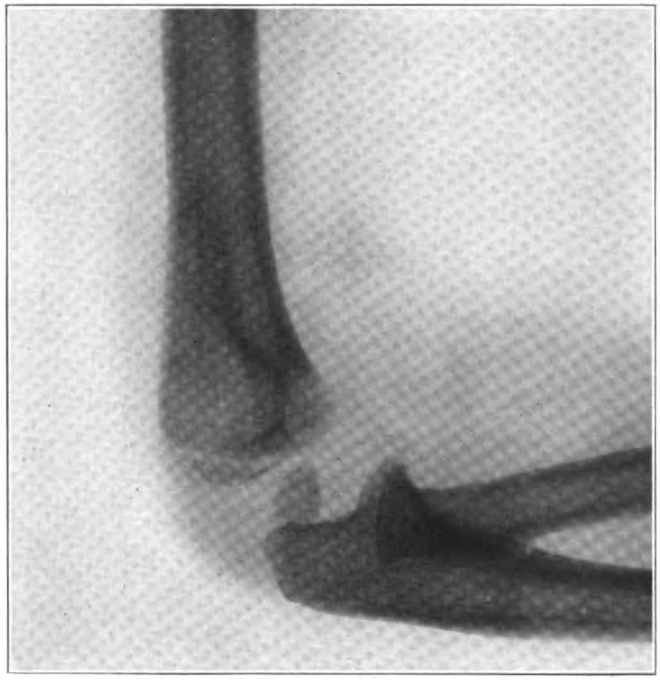


FIG. 89.

Digitized by Google

appear at the ages of the patients in question, and further that the internal condyle when it is apparent is on a level with the internal oblique line of the shaft of the humerus. Any displacement of the internal epicondyle is evidenced by the alteration in its position. Usually it takes a downward position with relation to the oblique line as is evidenced in Figure 90.

CASE XI. (Notes taken by Dr. H. B. Gessner.) Patient presented a suspected fracture of the right elbow. A roentgenogram was requested. The roentgen-ray report was: "Epiphyseal separation, lower end of humerus." The physical findings were negative.

CASE XII. Male, aged fifteen years, on November 14, 1918 presented an elbow which had been swollen since November 12th. There was no history of an injury (Fig. 91A and B).

Roentgenogram revealed: Supracondyloid fracture and separation of the olecranon process of the ulna.

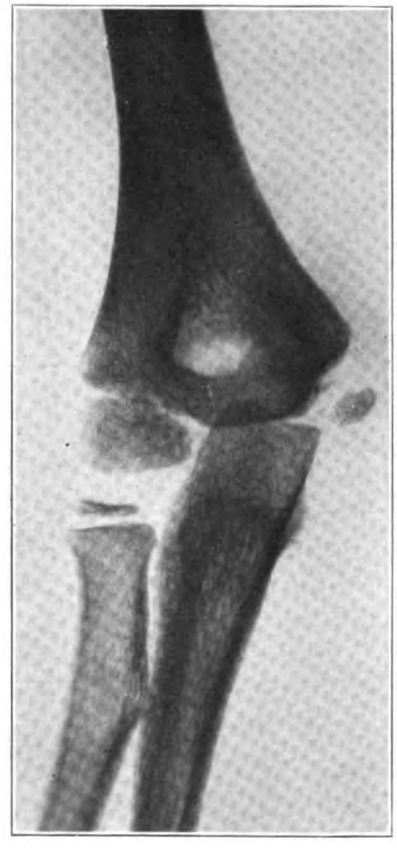


FIG. 90.

Digitized by Google

Interpretation at the present time in the light of study of normal joints is that this was a normal joint.

These errors could not have crept in had our roentgenologist known the normal.

DEDUCTIONS

The roentgen ray can be of inestimable value when proper interpretation is put on the pictures. This can be done only by having a clear knowledge of the normal. In order to compare the roentgenogram of a particular case, we must compare it with the average normal for that particular age.

A roentgenogram must not be depended on to show a fracture within an epiphysis in young children before the particular epiphysis has sufficiently ossified.

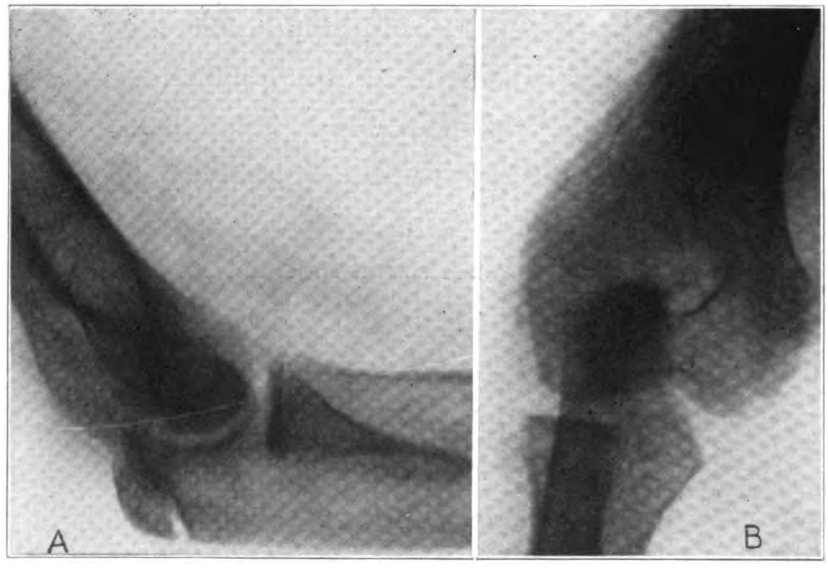


FIG. 91.

A knowledge of the normal elbow will prevent future errors by making possible the differentiation of normal epiphyses from fractures.

A disturbance of the relationship of certain planes mentioned in this work will enable the roentgenologist to state that there will be disturbance of function and deformity unless the condition is corrected. This particularly

Digitized by Google

applies to the overlapping of the shadow of the capitellum by the olecranon.

In some instances, there is certainty that the deformity has not been reduced, and from my experience I believe that you can prophecy that a cubitus varus will develop.

Delay in reducing the deformity gives opportunity for swelling to take place, after which the difficulty of treatment is increased, particularly with reference to the hyperflexed position.

Attention must be directed toward developing the external rotators of the humerus, otherwise patients who have supracondyloid fractures have a tendency frequently to continue carrying the arm in the position of internal rotation, which will give rise to a cubitus varus of muscular origin rather than of bony origin.

The history is of inestimable value; in a broad sense, it includes all of the facts relative to, as well as subjective and objective phenomena associated with, the injury. Many have empirically stated in the past that certain injuries are associated with a certain group of signs and symptoms. What is most to be desired is a diagnosis based on a logical interpretation of historical facts and symptoms as well as clinical manifestations. Every sign and symptom is present because of a definite change incident to the lesion present. Examination of an injured elbow should be undertaken in a systematic manner, with a full appreciation of what is to be gained by each step. The most evident phenomenon on inspection is the position—semiflexion, and diminished or lost carrying angle.

There are many causes for these phenomena. Due attention to each will enable the examiner to reach conclusions which may save the patient much

Digitized by Google

painful manipulation in an attempt to arrive at the final diagnosis. It is not to be understood that it is my belief that inspection will be all that is necessary, but it will be very helpful.

The normal carrying angle is the result of several factors, among which may be mentioned the obliquity of the lower end of the humerus as compared to the shaft of the humerus, and the consequent relative position of the articulation of the ulna with the humerus. Anything which will permit of greater freedom of motion of the ulna in a lateral direction on the humerus will alter the carrying angle. If the above is true, then we must consider the capsule of the elbow as well as the muscular attachments in the vicinity of the condyles.

Turning to our anatomies we find: "The capsular ligament surrounding the joint is very weak behind, stronger in front and very strong at the sides. The sides are commonly called the lateral ligaments. The lateral ligaments radiate from below to the tips of the condyles. The lateral ligaments of the normal joints should always be tense." (Piersol.)

From the foregoing, it follows logically that a tear of the lateral ligaments will give rise to an increase in the lateral mobility of the joint. If to the tear of the ligament is added a fracture through one of the condyles, or above the condyles, we will have not only the abnormal lateral mobility, due to the tear, but there will be added lateral mobility in the direction of the contraction of the group of muscles remaining attached to the shaft, being unopposed by the group torn away from the shaft.

Digitized by Google

If, therefore, we interpret the exaggerated lateral mobility, as evidence of an injury to the capsule and the contraction of these muscles attached to the shaft, we are in a position then to proceed with further examination, with some knowledge of the probable location of the injury.

Palpation always reveals pain at the site of the fracture. If then the two bits of information obtained by inspection and palpation are correlated with anatomic facts, it is reasonable to suppose that it will not be necessary to manipulate a great deal prior to taking a roentgenogram. Manipulation causes pain, and if the patient happens to be a child, as is often the case, the future handling of the case will be more difficult.

The picture must not be accepted as a final statement of the case, if it does not show a condition, belief in the existence of which is justified by examination.

This later statement is based on the fact previously stated that in the young the epiphyses are not evident roentgenographically, and a fracture through one of these does not show.

Under anesthesia, the examination should be continued. Oftentimes the small fragment which was not evident in the picture will be palpated and can be felt to slip back into its normal "bed." Following such manipulation the carrying angle has been seen to be restored, and flexion and extension accomplished within normal range.

Further, it is important after reduction to make a roentgenogram to determine whether the relationship of the capitellum to the sigmoid cavity has been restored. As mentioned before, it should lie well within this cavity and should not be overlapped by the shadow of the sigmoid cavity. If such a condition exists, the deformity has not been reduced, and failure to attend to this detail will result in a cubitus varus. The importance of this cannot be overestimated.

Incidentally, it should be borne in mind that a persistence of this deformity may result from two conditions: a relaxed or stretched capsule,

Digitized by Google

following the accident, and the overactivity of the internal rotators of the humerus (Case VI, Fig. 81A and B).

The importance of the integrity of the internal lateral ligaments has been emphasized by Sir Robert Jones, in connection with operation on the knee. The relaxation of the internal lateral ligament at the knee means a weak and wabbly knee. The same is true of the elbow, and the importance of this source of deformity is too little appreciated.

The position of the forearm with reference to the arm is important: to say hyperflexion and stop is not sufficient, because what is the proper position for one fracture is not the correct one for another. Only by reference to muscle attachments and origins can we be certain of the proper attitude. The rule to bear in mind is always to relax the muscles which are tending to increase the deformity by their contraction, and to bring the axis of the fragments over which you have control, into the plane of axis of the fragments over which you have no control, thus producing an equilibrium of forces.

Applied to the elbow, this can only be stated by naming the muscles attached about the elbow, and showing by diagrams their particular action, when acting harmoniously, and their action after an injury.

It is hardly necessary to restate what has often been stated, that hyperflexion is the position of greatest stability in supracondyloid fractures, because the triceps acts as a natural splint, and there is a relaxation of all of the flexors which have a tendency to bring the distal fragment into the bend of the elbow.

In fractures of the internal condyle, it is desirable to have not only hyperflexion, but also pronation of the forearm.

This is true because contraction of muscles attached to the shaft, particularly the brachioradialis, tends to supinate the forearm; the supinator brevis which arises from the external condyle and orbicular ligament

Digitized by Google

supinates the forearm, and probably by its contraction, following fractures of the internal condyle, which is often associated with a tear of the internal lateral ligament, tends to diminish the carrying angle.

The anconeus, which arises from the external condyle and is inserted into the ulna, aids the triceps in extending the arm, and also probably aids in altering the relative axis of the ulna to the humerus, thus exaggerating the cubitus varus deformity.

The contraction of the pronator teres, which originates from the internal condyle, tends to pronate the forearm and by its contraction pulls the loose fragment away from the shaft. Therefore, in order to maintain a position of stability, one in which there will be the least tendency to reproduction of deformity, hyperflexion and pronation will be found most desirable.

In fractures of the external condyle, the position of greatest stability is one of hyperflexion and supination, for these reasons:

Pronation would allow the pronator teres to pronate the forearm and thus pull the external condyle away from the shaft. In supination the pronator is opposed by the artificial force of the bandage, and contraction of the supinator brings the external condyle into closer contact with the humerus.

Reduction having been accomplished and the proper dressing applied, the difficulty often arises of keeping the bandage from slipping from the elbow. It has been found useful to have a conical bag made, the apex down. In such a bag the hyperflexed forearm and arm are slipped and the whole is supported by tapes tied around the neck.

The after-care is too important not to have a few words said about it.

Prolonged hyperflexion necessarily results in contractures of the flexor muscles. Therefore, it is essential to diminish the flexion as soon as it is safe. This may be begun about the tenth day. At each dressing contrast baths, massage and passive motion are given. The range of motion should be limited by evidence of pain. Pain is indicative of injury to the part. Flexion and

Digitized by Google

extension within a given arc should be done once at each dressing during the early after-care of these patients.

Plaster molded splints should be used.

A source of annoyance is the tendency toward internal rotation, of the arm as a whole. This is due to the position of hyperflexion, which is accompanied by an internal rotation of the shoulder. In order to overcome this tendency, one must insist on rotation outward of the shoulder at the very earliest moment. Shoulder movement will not disturb the position of the fracture of the elbow if the bandage is snug. Some may consider these statements highly theoretical. To them, I commend neglect of this precaution, and they will later be convinced of the truth.

During the first twenty-four hours, it is urgent that the part be observed closely. Volkmann's ischemia may result from a tight bandage which has been applied for as short a period as six hours. A case which was treated at the Touro Infirmary resulted from the bandage remaining on for twelve hours.

The application of the bandage in the position of hyperflexion requires special care. All bandages should include the hand. If the bandage does not include the hand, secondary swelling of the hand will be greater than that of the forearm, and any form of gauze sling around the wrist will cause a great constriction at this level. This will create a vicious circle. This difficulty can be overcome by bandaging the hand as well as the forearm and arm. A rubber tube used as a sling is preferable to a gauze bandage, because the elasticity of the former allows for relaxation if swelling occurs.

After the fourth week, it is very important that active as well as passive movement be encouraged. Massage and resistive exercises contribute in a large measure to a perfect result.

The following cases have been treated along these lines and represent the work as it is done in our clinic and private work.

Digitized by Google

CASE XIII. Male, aged thirteen years, on April 2nd, while jumping rope, fell on his outstretched hands. He had had no treatment since the accident. He had full use of his fingers, but could not raise his arm up to his head nor could he bend the elbow.

April 4, 1918. Examination under ether anesthesia revealed: right elbow, diminished carrying angle, cubitus varus, limited extension and flexion to about 130°; pain on pressure over the internal condyle, crepitus over the internal condyle, and marked deformity. As soon as the deformity was reduced, we noticed a return of the carrying angle.

Diagnosis. Fracture of the internal condyle of the humerus. The arm was placed in hyperflexion. Examination of the left arm revealed that it could be extended and flexed at

FIG. 92. CASE XIII.

FIG. 93. CASE XIII.

will. On complete extension of the elbow, the internal condyle was seen to be more prominent. There was undue prominence of the internal condyle; no change in the contour, and small fracture of the internal condyle.

Digitized by Google

The roentgenogram revealed fracture of the internal condyle of the right humerus, and fracture of the internal condyle of the left humerus. April 9th and April 20th, the arm was redressed. April 22nd, pronation and supination were unimpaired. There was no loss of carrying angle on either side. May 2nd, the left arm showed full extension and good flexion: the right arm could be extended to about 130° without pain. All dressings were removed. Report of a roentgenogram, requested June 29th, stated: "Suggestive of an old fracture, but position is exceptionally good." Examination, November 20, 1920 (two and a half years after accident) revealed: perfect extension, perfect flexion, normal carrying angle, and no loss or limitation of pronation or supination (Figs. 92 and 93).

FIG. 94. CASE XIV.

CASE XIV. Male, aged twelve years, was admitted Feb. 10, 1917, with a fracture of the radius near the base—supracondyloid fracture of the humerus. He had fallen on the outstretched hand.

Examination revealed swelling about the elbow, abnormal lateral mobility and crepitus. Above the wrist, there was a backward displacement of the hand on the forearm. The roentgenogram revealed: fracture of the lower end of the radius and supracondyloid fracture of the humerus (Fig. 94).

Digitized by Google

The deformities were reduced under anesthesia. Hyperflexion was maintained by light plaster splints.

FIG. 95. CASE XIV.

March 13, 1917, flexion was 30°, extension to 130°. There was no pain and no deformity March 24th, he was able voluntarily to extend the elbow to 150° without pain. There was no deformity. Pronation and supination were unimpaired (Fig. 95).

April 3rd, supracondyloid fracture position was fairly good. At my request the child appeared in the clinic, October 30, 1920. Examination at that time showed perfect function of the elbow, complete extension and flexion. There was no limitation of pronation or supination. He had a normal carrying angle. A roentgenogram requested at this time revealed a previous line of fracture (Figs. 96A and B).

Comment. The combination of a fracture of the base of the radius following a fall on the outstretched hand requires not only the hyperflexed position but in addition a palmar plaster splint.

CASE XV. Male, aged seven years, admitted January 10, 1920, with a supracondyloid fracture of the left humerus. Sunday evening, January 4, 1920, the patient had been running along the street when he fell in the gutter on his left arm. He came to the hospital the same evening and had a cast put on. He went home after a week's stay in the hospital. The arm was put up, January 10th, in the Smith-Jones position. He returned, January 12th, and the arm was redressed. He has been anesthetized three times; once in my clinic. January 15th, a right angle splint was applied.

January 24th, flexion was limited and painful; a splint at 160° was applied. Roentgen-ray report, January 27, 1920: old supracondyloid fracture of the left humerus, with some backward displacement of the lower fragment.

The child was resistant to any effort to do anything for him. The mother was advised to continue contrast baths and have the child carry weights.

Digitized by Google

February 12th, the child was resistant to treatment. The elbow was flexed and he would not allow any one to extend it. The mother was advised of poor results unless she forced the child to carry out the treatment. He was able to extend the arm to about 150°. He flexed the elbow to 60°. Hot and cold applications and exercise were continued.

February 28th, flexion and extension were still limited. Pronation and supination were limited. The same treatment was continued.

March 13th, flexion and extension were still slightly limited. There was still a large amount of callus surrounding the old fracture (supracondyloid). Forced hyperflexion was painful.

FIG. 96. CASE XIV.

November, 1920, at my request, the child came to the clinic for observation. At this time, examination revealed: complete flexion, pronation and supination, and extension, and a normal carrying angle in both elbows (Figs. 97 and 98).

Digitized by Google

Comment. The original attempts at reduction made by others did not succeed. When I saw the child, there was so much swelling that hyperflexion could not be maintained.

Persistent after-care will overcome many apparent muscle contractures.

CASE XVI. Male, aged ten years, was admitted November 5, 1918, with a supracondyloid fracture. He had fallen in a ditch, December 3rd, and had struck the left elbow. He was unable to straighten the arm or to bend the elbow. The left forearm was swollen.

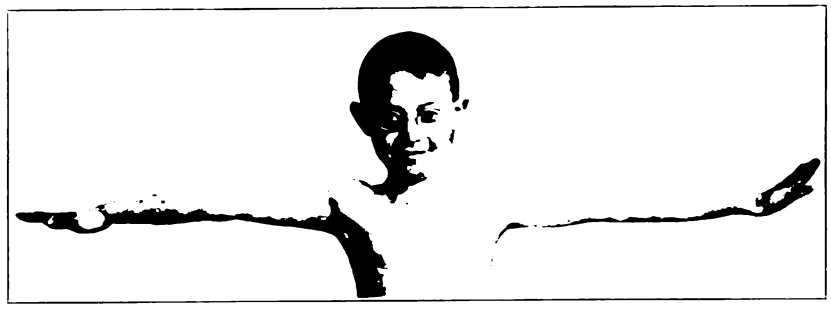


FIG. 97. CASE XV.

FIG. 98. CASE XV.

Digitized by Google

Measurements of the left elbow were 21 cm., right 17 cm. There was no pain over either condyle and no pain over the olecranon process. The head of the radius rotated with the shaft. He did not complain of pain along the course of the ulna. There was a diminished carrying angle. The fracture was reduced under general anesthesia, and the usual dressing was applied. The roentogenogram revealed "epiphyseal separation lower end of the condyles of the humerus."

December 12th. A right angle plaster splint was applied.

December 21st. All dressing was removed.

FIG. 99. CASE XVI.

April 22, 1919. There was no limitation of flexion or extension. The carrying angle was normal. The child said, when asked what he did with the arm, "I do all I want."

At my request the child came to the clinic, November 20, 1920. There was a normal carrying angle; no difference in the size of the two elbows; no limitation of flexion or extension of the two elbows. Pronation and supination were unimparied (Fig. 99).

The roentgenogram revealed no visible bone injury of the left elbow (November 20, 1920).

CASE XVII. Male, aged ten years, admitted, June 8, 1918, with a "posterior dislocation of the elbow—supracondyloid fractures." He had fallen from a bicycle the day before and had struck his elbow on the car track. He was able to raise the arm, but could not bend the elbow. Examination revealed swelling and ecchymosis of the right elbow, abnormal mobility, no change in the contour of the ulna, abnormal mobility and crepitus just above the condyle.

Under ether anesthesia, the deformity was reduced. On account of the great amount of swelling around the elbow it was impossible to put it up in hyperflexion; anterior and posterior plaster splints were made, and the arm was put up at a right angle. A roentgenogram was requested.

Digitized by Google

June 13th, the swelling had disappeared, and we were able to put the arm up in hyperflexion.

At my request the child came to the clinic, November 18, 1920. There was no limitation of flexion or extension, and no loss of carrying angle. Resistive exercise showed no loss of muscle power; if anything, the right arm showed better muscular development than the left (Fig. 100).

FIG. 100. CASE XVII.

CASE XVIII. Male, aged ten years, suffered a fracture of the internal condyle of the humerus. While playing baseball, he threw the ball, and a sudden pain developed in the right elbow. There were pain, swelling, and abnormal mobility. The right elbow was larger than the left. The right measured 7¾ cm., the left 7⅛ cm. The attitude was one of loss of carrying angle. He held the right arm partially extended. There was marked swelling above the internal condyle, and no change in normal relationship of landmarks of the elbow, but there was considerable pain over the internal condyle. Flexion beyond a right angle was impossible on account of pain. Bandages were removed and right angle splints were applied. The roentgenogram revealed epiphyseal separation of the condyles of the humerus. Position was fairly good.

April 22, 1919, there was no limitation of flexion or extension. There was normal pronation and supination, and no deformity (Figs. 101 and 102).

CASE XIX. Female, aged ten years, suffered a fracture of the internal condyle. She fell from a wagon, July 27, 1917, and injured her elbow. Examination revealed complete loss of carrying angle, swelling of the elbow, pain over the internal condyle, and all motions about the elbow painful.

The roentgenogram revealed a supracondyloid fracture of the humerus. Position was good. Under ether anesthesia, the deformity was reduced, the carrying angle returned, and

Digitized by Google

the elbow put in hyperflexion. On the tenth day the hyperflexed position was changed to one of right angle. There was no pain.

September 13, 1917. Extension was possible to 160°; flexion beyond 45°. There was no pain or deformity. The patient was advised to continue exercise.

September 29, 1917. There was perfect flexion and extension.

FIG. 101. CASE XVIII.

FIG. 102. CASE XVIII.

November 9, 1920. At my request the patient appeared in the clinic for observation, at which time the following was noted: carrying angle of both elbows was the same; there was no limitation of flexion, pronation or supination (Figs. 103 and 104).

CASE XX. Female, aged fourteen years, admitted, June 13, 1919, with a supracondyloid fracture of the humerus; had fallen about 4 feet, striking the left arm on the pavement. There were swelling and pain around the elbow, an ecchymotic area over the external

Digitized by Google

condyle, and crepitus on palpation. The transverse diameter of the elbow was increased. Under anesthesia the elbow was placed in hyperflexion.

FIG. 103. CASE XIX.

FIG. 104. CASE XIX.

Roentgenogram: The left elbow joint shows a supracondyloid fracture of the left humerus. There is a splitting into the olecranon process of the ulna.

June 14, 1919. The patient had not suffered any pain.

June 22nd. The dressing was removed. There were ecchymosis and swelling over the external condyle. The arm was placed at a right angle in complete supination, and a plaster splint applied.

June 24th. It was placed at an angle of 110°.

June 28th. It was placed in almost complete extension.

July 1st. There was flexion to about 60° and complete extension. A straight plaster splint was applied.

July 3rd. The splint was reapplied.

Digitized by Google

The roentgen-ray report was: "Repair of fracture previously observed is excellent, but there is a decided thickening of the periosteum throughout the lower shaft of the humerus," July 3, 1919.

One year and five months after the accident, November 8, 1920, there was a normal carrying angle; perfect flexion and extension; no limitation of pronation nor supination (Figs. 105 and 106)

FIG. 105. CASE XX.

FIG. 106. CASE XX.

Digitized by Google

Chapter IV

THE NORMAL WRIST

Review of the Literature

In a review of the anatomic and surgical literature referring to the wrist the complexity of the development of this joint is evident.

This study includes the lower radial and ulna epiphyses, the carpal bones, metacarpals and the phalanges. This chapter might properly be designated the "development of the hand and wrist."

It is necessary to consider the individual bones in any review. We will therefore consider the radius first and the others in the natural sequence.

"The lower epiphysis of the radius appears about the end of the second year and unites with the shaft about the nineteenth to twenty-third year." (Poland's Skiagraphic Atlas.)

"About the end of the second year ossification commences in the lower epiphysis. Union takes place at the eighteenth or nineteenth year." (Gray's Anatomy.)

"The lower end of the radius begins to ossify during the second year, and unites at the twentieth year." (Morris' Anatomy.)

"The lower end of the radius appears at the end of the second year and unites at the twentieth year." (Gray's Anatomy.)

"The lower epiphysis appears about the second year and unites to shaft at from the nineteenth to the twentieth year." (Scudder's Treatment of Fractures.)

"The center for the lower end appears shortly before the upper one (fifth year) but does not unite with the shaft until the twentieth year." (Roberts and Kelly's Fractures.)

Digitized by Google

ULNA

"About the fourth year a separate osseus nucleus appears in the middle of the head, which soon extends into the styloid process. At about the twentieth year it becomes united to the shaft." (Gray's Anatomy.)

"At about five one (center) appears for the head and styloid process: this joins the shaft at eighteen." (Piersol's Anatomy.)

"The nucleus for the epiphysis appears in the sixth year and unites with the shaft about the eighteenth to the twentieth year." (Morris' Anatomy.)

"The lower epiphysis appears during the fourth year, and joins the shaft about the twentieth year." (Gray's Anatomy.)

"The center for the lower epiphysis joins the shaft from the eighteenth to the twentieth year." (Roberts and Kelly's Fractures.)

"The lower epiphysis of the ulna appears about the fourth or fifth year and unites with the shaft about the eighteenth to the twentieth year." (Poland's Skiagraphic Atlas.)

TABLE IV

Author	Lower Epiphysis Radius		Lower Epiphysis Ulna	
	Appears	Ossifies	Appears	Ossifies
Gray	End 2nd yr.	18th or 19th yr.	4th yr.	20th yr.
Morris (Jackson)	2nd yr.	20th yr.	6th yr.	20th yr.
Gray (Lewis)	End 2nd yr.	20th yr.	4th yr.	20th yr.
Scudder	About 2nd yr.	19th to 20th yr.		
Roberts and Kelly	Shortly before 5th yr.	20th yr.		18th to 20th yr.
John Poland	End 2nd yr.	19th to 23rd yr.	4th or 5th yr.	18th to 20th yr.
Isidore Cohn	6 mos.	20th to 21st yr.	6th to 7th yrs.	20th to 21st yr.

Digitized by Google

CARPAL BONES

"*First Year.* Ossification of the magnum, having commenced at the eighth month, is now well advanced, the nucleus at this period being of an oval shape. The nucleus of the unciform is of a rounded shape. None of the other bones has as yet any point of ossification.

"*Second Year.* Cuneiform shows rounded center of ossification about its center. It is absent in the next skiagram of the third year and in the skiagram of the fifth year.

"*Third Year.* Centers of ossification for the magnum and unciform only are seen in this instance.

"*Four and a Half Years.* Ossification of magnum and unciform assumes the normal shape of the bones. Granules of ossification in the trapezium and trapezoid are faintly visible. The nucleus of the cuneiform begins to assume the normal shape of bone, that of the semilunar is of a rounded form.

"*Fifth Year.* The nucleus of the unciform assumes shape of bone and the centers of ossification of the scaphoid and trapezium and trapezoid are very distinct.

"*Seventh Year.* The center of ossification of the trapezoid above the metacarpal bone of index finger is now very much enlarged.

"*Ninth Year.* A faint shadow of the hook-like process of the unciform bone is noticeable.

"*Thirteenth Year.* Ossification of all the carpal bones now complete. The shape of the fully developed bones clearly defined. The shadow of the pisiform bone is noticeable.

"*Anatomy of the Bones of the Carpus.* At birth all the bones of the carpus are entirely cartilaginous.

"There is usually a single nucleus of ossification for each bone, which appears in the magnum towards the end of the first year, in the unciform at

Digitized by Google

about the second year, in the cuneiform at the third year, in the semilunar at the fourth year, in the trapezium at the fifth year, in the scaphoid at the sixth year, in the trapezoid at the eighth year, and in the pisiform at the twelfth year.

"The scaphoid sometimes commences ossification with a second nucleus close to the first and the unciform occasionally has an independent center for its hook-like process. Serres describes a second center for the semilunar also.

"There are no epiphyses to these bones.

"An occasional ossicle, the central, is sometimes seen on the dorsal aspect of the carpus situated between the scaphoid, trapezoid and magnum." (Poland's Skiagraphic Atlas.)

"Each bone is developed from a single center of ossification. At birth they are all cartilaginous.

"Ossification proceeds in the following order: In the os magnum and unciform an ossific point appears during the first year; in the cuneiform at the third year; in the trapezium and semilunar at the fifth year; in the scaphoid at the sixth year; in the trapezoid during the eighth year; and in the pisiform about the twelfth year." (Gray's Anatomy.)

"Ossification occurs from one center for each bone; but according to some authorities, the unciform and the scaphoid have two centers. The former and the os magnum are the first to ossify, the process beginning in the latter part of the first year. The order of its appearance in the other bones is very uncertain. Those of the first row, excepting the pisiform, contain bone by the end of the first five or six years. These are followed by the trapezium and the trapezoid, so that by the eighth year the process has begun in all the carpals save the pisiform, in which it begins about the twelfth year." (Piersol's Anatomy.)

"In the hand all bones are ossified at birth, except the carpus, in which the centers of ossification in the os magnum and unciform may be seen very

Digitized by Google

rarely. The cuneiform is seen at the third year, the trapezium and semilunar at the fifth year, the scaphoid at the twelfth year."[1]

"All the carpals ossify from a single center and all are cartilaginous at birth. The center for the os magnum and unciform appear during the first year; and for the other bones between the third and ninth years." (Roberts and Kelly's Fractures.)

TABLE V

TIME OF APPEARANCE OF OSSIFICATION WITHIN CARPAL BONES

Author	Scaphoid	Semi-lunar	Cunei-form	Pisi-form	Trape-zoid	Trape-zium	Unci-form	Os Magnum
Gray	6th yr.	5th yr.	3rd yr.	12th yr.	8th yr.	5th yr.	1st yr.	1st yr.
Piersol	First 5 or 6 yrs.	First 5 or 6 yrs.	First 5 or 6 yrs.	12th yr.	By the 8th yr.	By the 8th yr.	1st yr.	1st yr.
Roberts and Kelly		All of these from 3rd to 9th yr.					1st yr.	1st yr.
Kreuscher	12th yr.	5th yr.	3rd yr.		5th yr.		May be seen at birth	
Isidore Cohn	Between 4 and 5 yrs.	4 yrs.	Between age of 2 and 3 yrs.	10th to 13th yr.	5th to 6th yr.	5th to 6th yr.	Before 6th mo.	Before 6th mo.
Poland	5th yr.	4½ yrs.	During 2nd yr.	13th yr.	4½ yrs.	4½ yrs.	Before end of 1st yr.	Before 8th mo.

METACARPALS

"*Development.* Each bone has two centers, a primary one for the shaft, appearing early in the third month of fetal life, and one for an end, appearing in the third year. The secondary center is for the distal end in the four inner metacarpals and in the proximal of the first—that is, at the end towards

[1] Kreuscher, P. H. A study of the development of the epiphysis. *Surg. Gynec. & Obst.*, 1918, XXVII, v, 480.

Digitized by Google

which the nutrient artery does not run. They fuse at about eighteen." (Piersol's Anatomy.)

"The first is the only metacarpal that has an epiphysis at its base, normally, and for this reason it is considered by some as a phalanx, in which the epiphyses are always at the base. There is usually a scale-like epiphysis on the head of the first metacarpal which makes its appearance about 8 or 10 and rapidly unites with the head.[2]

"The metacarpals are preformed in cartilage and ossify from a diaphyseal center for the shafts and an epiphyseal center in the base. The epiphyseal centers appear after birth." (Roberts and Kelly's Fractures.)

Note. No mention is made of the period of ossification.

PHALANGES

"*Development.* The phalanges have each a center for the shaft and one for the proximal end. The former appears in the latter half of the third month of fetal life at about the same time in the terminal and proximal row. Ossification begins in the epiphyses in the third year or later. They are fused by eighteen.

"Sesamoid bones occur in the metacarpophalangeal joints. A pair is constant in the joint of the thumb." (Piersol's Anatomy.)

PART II

OBSERVATIONS BASED ON A STUDY OF THE NORMAL WRIST

I. At birth none of the epiphyses of the wrist and hand has begun to ossify.

II. Ossification begins in the lower epiphysis of the radius during the first six months of life.

III. Reference to the section devoted to the literature as well as to the tables will show that the various anatomies and works on fractures state

[2] Skillern, P. G. Inconstant extra-epiphysis at base of second metacarpal, *Ann. Surg.*, 1915, XLI, iii, 374.

Digitized by Google

that the lower epiphysis of the radius begins to ossify about the second year, or the end of the second year. *Our observation indicates that ossification begins during the first half of the first year.*

IV. Two of the carpal bones, the os magnum and unciform, begin to ossify during the first six months after birth.

V. Between the ages of two and three years a third carpal (the cuneiform) begins to ossify. At times a fourth (the semilunar) begins to ossify.

VI. Before three years of age the epiphyses of all the metacarpals and phalanges show definite evidence of ossification. The epiphysis of each of the metacarpals except the first is found at the distal end or at the head of the shaft; the epiphysis of the first metacarpal is located at the base.

VII. At this period a single epiphysis begins to ossify at the base of the phalanges.

VIII. During the latter part of the fifth year seven carpals have ossified sufficiently to leave shadows. The shadow of the scaphoid is very small, showing that ossification has just begun. The epiphysis of the first metacarpal and phalanges also begins to ossify about this period.

IX. The lower epiphysis of the ulna does not begin to ossify before the seventh year.

X. The pisiform is not normally ossified until the tenth year and is not constant until the thirteenth year.

XI. On the metacarpals the epiphyses are completely ossified and united to their respective shafts by the eighteenth year.

XII. The epiphysis and diaphysis of the phalanges unite about the eighteenth year.

XIII. Complete ossification and union between the lower radial and ulna epiphyses with their respective shafts take place between twenty and twenty-one years of age.

Digitized by Google

Interpretation of Individual Roentgenograms of the Normal Wrist at Various Ages (Plates xix–xxv)

Digitized by Google

PLATE XIX

Two Months (Fig. 107). There is no evidence of ossification within the lower epiphyses of the radius or ulna.

None of the carpal bones has begun to ossify. The diaphyses of all the metacarpals have ossified, but none of their epiphyses shows evidence of ossification.

The diaphyses of the phalanges are ossified, but none of their epiphyses shows evidence of ossification.

Six Months (Fig. 108). Ossification has begun in the nucleus of the lower epiphysis of the radius.

The center of ossification within this nucleus occupies the mid-portion of the base of the radius.

Two of the carpal bones have begun to ossify. These are probably the os magnum and unciform, as they are close to the fourth and fifth metacarpals.

Fifteen Months (Fig. 109). The lower epiphysis of the radius at this time is about three times the size noted at six months. The two carpal bones have ossified in like proportion. None of the other epiphyseal nuclei has begun to ossify.

Two Years and Two Months (Fig. 110). There is very little change to be noted when this picture is compared with the one taken at fifteen months.

Digitized by Google

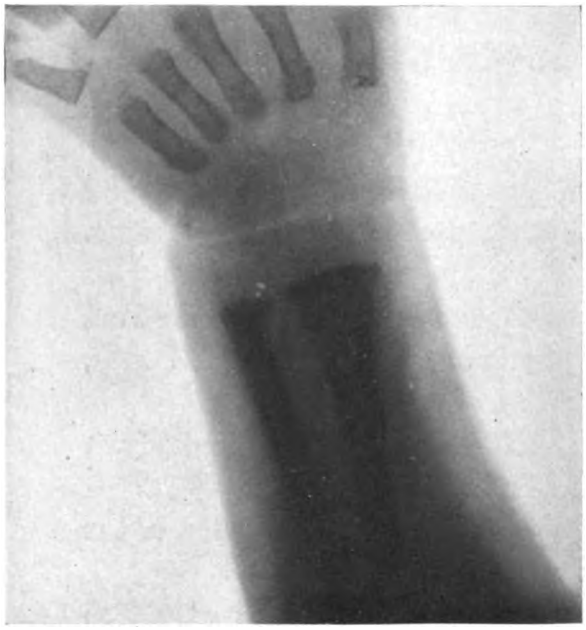


FIG. 107. TWO MONTHS.

FIG. 108. SIX MONTHS.

FIG. 109. ONE YEAR, THREE MONTHS.

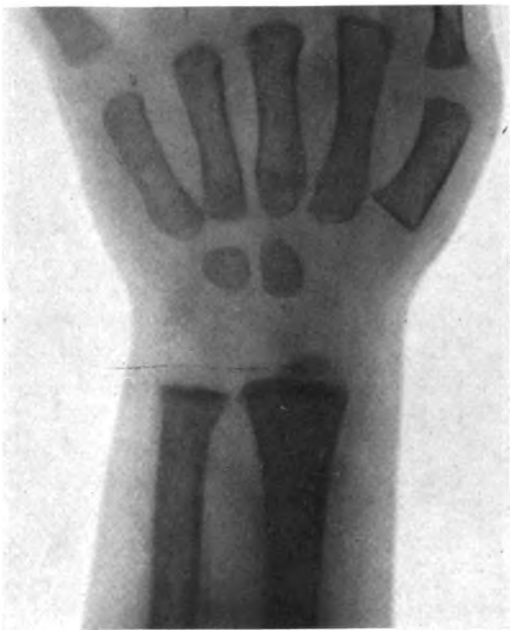


FIG. 110. TWO YEARS, TWO MONTHS.

Digitized by Google

PLATE XX

Two Years and Eight Months (Fig. 111). The lower epiphysis of the radius now occupies more than one-half the diameter of the base of the diaphysis and it is closely approximated to it.

There are now four carpal bones ossified sufficiently to leave definite shadows, and they are arranged in two rows, probably the os magnum, unciform, semilunar and cuneiform.

The nucleus of the epiphysis for all of the metacarpals except the first, has begun to ossify at this time. The epiphysis of the second, third, fourth, and fifth is found at the head or distal portion of the metacarpal.

The epiphysis of the first phalanx of all fingers has begun to ossify at this time, the nucleus being found at the base of the phalanx.

Ossification has not begun in the epiphysis of the first phalanx of the thumb.

Two Years and Ten Months (Fig. 112). Epiphyses and carpals which have begun to ossify at this time:

1. Lower epiphysis of radius.
2. Three carpal bones, os magnum, unciform and cuneiform.
3. The epiphysis for each of the metacarpals except the first.
4. An epiphysis for the first phalanx of all fingers. The epiphysis for the first phalanx of the thumb has not begun to ossify.

Three Years (Fig. 113). Epiphyses and carpals which show evidence of ossification:

1. The lower epiphysis of the radius.
2. Three carpal bones, the same as in the preceding picture.
3. The epiphysis of all the metacarpals have increased markedly in size. The epiphysis for the first metacarpal has appeared by this time. This epiphysis is at the base, or proximal end, of the metacarpal.
4. The epiphysis for the first phalanx of the thumb has begun to ossify. It is to be found at the base instead of at the head as in the other phalanges.
5. Each of the phalanges now has a single epiphysis which shows evidence of ossification. The epiphysis is located at the head of the diaphysis.

Four Years (Fig. 114). Epiphyses and carpal bones which show evidence of ossification:

1. The lower epiphysis of the radius now occupies about two-thirds of the base of the radius.
2. There is no evidence of an epiphyses for the lower end of the ulna.
3. Five carpal bones are evident: the os magnum, unciform, semilunar and cuneiform have attained a fair size and the scaphoid is represented by a very small shadow.
4. The epiphyses for the metacarpals and phalanges show only progressive changes.

Digitized by Google

FIG. 111. TWO YEARS, EIGHT MONTHS.

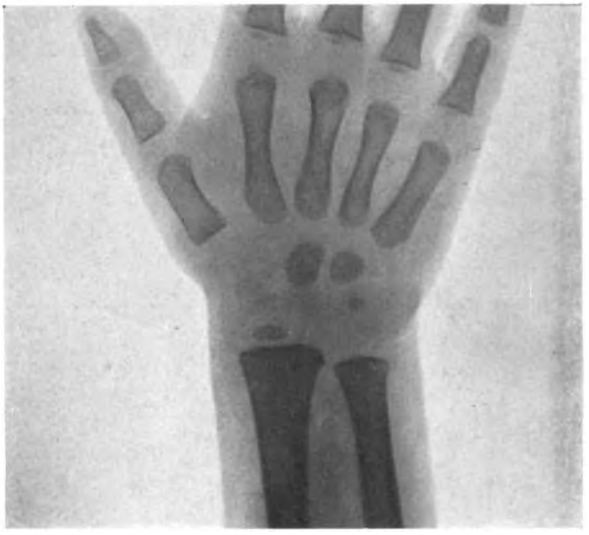


FIG. 112. TWO YEARS, TEN MONTHS.

FIG. 113. THREE YEARS.

FIG. 114. FOUR YEARS.

Digitized by Google

PLATE XXI

Five Years and Eight Months (Fig. 115). The ossifying lower epiphysis of the radius is now large enough to occupy about two-thirds of the base of the shaft; furthermore, it is now wedge-shaped, with the base of the wedge on the radial side.

The epiphysis for the lower end of the ulna has not begun to ossify.

Seven carpal bones are now evident; the trapezoid, trapezium and scaphoid have begun to ossify at this time. The nucleus for the scaphoid is very small.

Seven Years (Fig. 116). The lower epiphysis of the radius occupies nearly the entire circumference of the base of the shaft. The epiphysis is closely approximated to the diaphysis near the middle, giving the impression that ossification between epiphysis and diaphysis proceeds centrifugally.

The lower epiphysis of the ulna has begun to ossify.

All the carpal bones have increased markedly in size. The only one not yet ossified is the pisiform.

Eight Years and Six Months (Fig. 117). The epiphysis of the lower end of the radius is on a much lower level than the ulna epiphysis.

The ulna (lower) epiphysis has increased to the extent that it occupies about one-half the diameter of the lower end of the diaphysis of the ulna.

The scaphoid has increased relatively more than any of the carpal bones.

Nine Years (Fig. 118). This is similar in all respects to the preceding figure except for a more marked development.

There is a peculiarity of the distal portion of the first metacarpal, namely an irregular line from within out, which might easily be mistaken for a fracture.

Digitized by Google

FIG. 115. FIVE YEARS, EIGHT MONTHS.

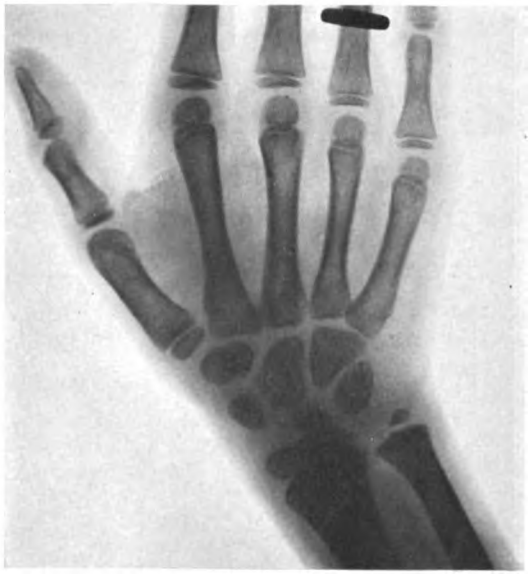


FIG. 116. SEVEN YEARS.

FIG. 117. EIGHT YEARS, SIX MONTHS.

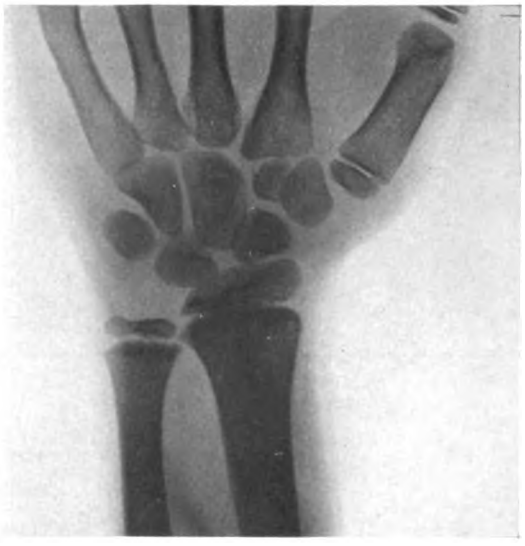


FIG. 118. NINE YEARS.

Digitized by Google

PLATE XXII

Nine Years and Five Months (Fig. 119). This is included to demonstrate the "wide separation" which may normally exist between a diaphysis and its epiphysis.

Ten Years (Figs. 120 and 121). The lower epiphyses of the radius and ulna now have downward projections for the respective styloids.

Digitized by Google

FIG. 119. NINE YEARS, FIVE MONTHS.

FIG. 120. TEN YEARS.

FIG. 121. TEN YEARS.

Digitized by Google

PLATE XXIII

The pisiform has begun to ossify but is not constantly found at this age. (See Fig. 122, age ten years.)

The first metacarpal presents a peculiar line near its head, which can easily be mistaken for an incomplete fracture (Figs. 121 and 123).

Eleven Years (Fig. 123). The pisiform has not begun to ossify in this instance. There is a close approximation between the lower radial epiphysis and the diaphysis. The ulna epiphysis covers the entire lower end of the diaphysis. There is now a downward projection of the inner aspect of the epiphysis for the styloid process.

Thirteen Years (Fig. 124). The lower epiphysis of the radius presents a distinct wedge-shaped appearance; the greatest diameter of the wedge corresponds to the styloid process. The epiphyseal line is still well marked.

The lower epiphysis of the ulna has a well-marked downward projection which corresponds to the ulna styloid. All the carpals have assumed the contour of the well-formed bone. The pisiform is almost constantly seen at this age. Its absence is the exception. (See Fig. 125.)

Ossification within the epiphysis of the metacarpals seems to proceed from within outward; at this time there is partial ossification of the epiphysis and the diaphysis.

Digitized by Google

FIG. 122. TEN YEARS.

FIG. 123. ELEVEN YEARS.

FIG. 124. THIRTEEN YEARS.

FIG. 125. THIRTEEN YEARS.

Digitized by Google

PLATE XXIV

Fifteen Years (Fig. 126). The styloids of the radius and ulna are now becoming more evident as a downward outgrowth of their respective epiphyses. There is also evidence of beginning ossification of the epiphyseal lines.

The pisiform is now almost completely ossified, and its shadow overlaps the cuneiform.

Fifteen Years (Fig. 127). This illustration shows a more marked development of all the epiphyses.

Seventeen Years (Fig. 128). This rather exceptional illustration is introduced to show that at seventeen years you may see a complete ossification of all the epiphyses of the hand and wrist.

Eighteen Years (Fig. 129). The lower epiphyses of the radius and ulna are completely ossified but the epiphyseal line is still evident, showing that there is as yet no bony union with the shaft.

The metacarpal epiphyses are all completely ossified and united with the shaft.

All the carpals have completely ossified.

Digitized by Google

FIG. 126. FIFTEEN YEARS.

FIG. 127. FIFTEEN YEARS.

FIG. 128. SEVENTEEN YEARS.

FIG. 129. EIGHTEEN YEARS.

Digitized by Google

PLATE XXV

Nineteen Years (Fig. 130). There is complete ossification of the radial and ulna epiphyses but incomplete ossification of the epiphyseal line.

The carpals have completely ossified.

Complete ossification of the metacarpal and phalangeal epiphyses and union with their respective shafts.

Nineteen Years and Eight Months (Fig. 131). There is still evidence of an incompletely ossified epiphyseal line at the lower end of the radius and ulna.

Twenty-One Years (Fig. 132). Complete ossification and union of all epiphyses and diaphyses.

Digitized by Google

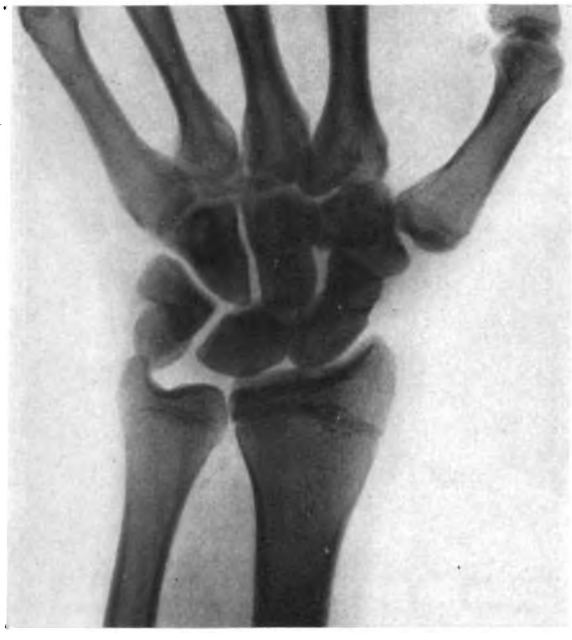


FIG. 130. NINETEEN YEARS.

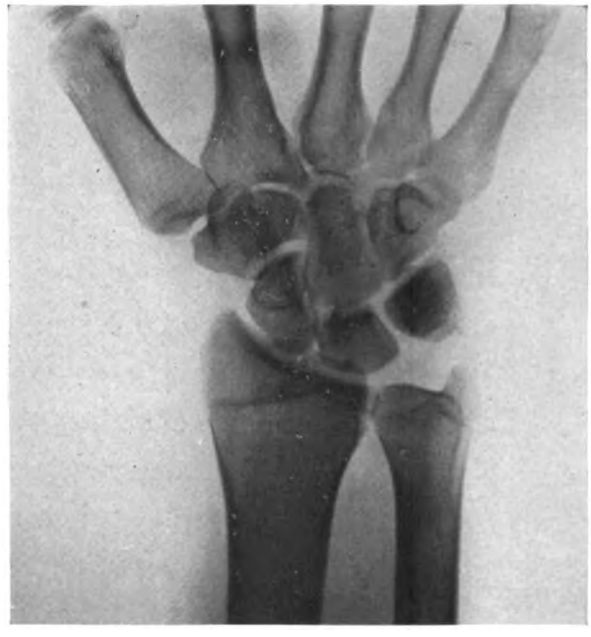


FIG. 131. NINETEEN YEARS, EIGHT MONTHS.

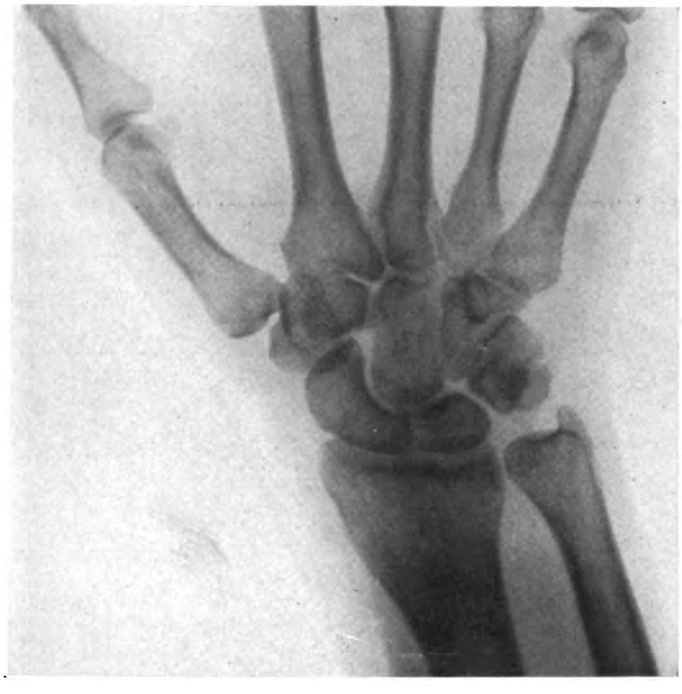


FIG. 132. TWENTY-ONE YEARS.

Digitized by Google

Chapter V

THE NORMAL HIP

Review of the Literature

Poland states that "the epiphysis for the head of the femur begins to ossify about the tenth month and that union between the epiphysis and diaphysis is completed by the nineteenth year.

"The epiphysis for the great trochanter appears during the fourth year and unites at the age of eighteen or nineteen.

"The lesser trochanter appears at thirteen and unites during the eighteenth year."

"The junction of the epiphyses to the shaft of the bone does not begin until after puberty, and is not completed until the twentieth year." (Mears' Practical Surgery.)

"Epiphyseal union is said to take place at the age of eighteen."[1]

"The upper epiphysis of the femur develops from three distinct centers for the head, the greater trochanter and lesser trochanter. These are united in reverse order of appearance of their ossific nuclei so that the lesser trochanter is united to the shaft about the seventeenth year, the greater about the eighteenth year and the head from the eighteenth to the nineteenth year. The neck is formed by an extension of ossification from the shaft."[2]

"The epiphysis for the head develops in the first year and joins the neck at the eighteenth or nineteenth year.

"One (epiphysis) for the greater trochanter develops in the fourth year and joins the shaft at the eighteenth year.

[1] Bradford, E. H. Three cases of separation of the epiphyses at the head of the femur. *Boston M. & S. J.*, 1892, CXXVI, 212.

[2] Tubby, A. H. Traumatic separation of epiphyses of the lower extremity. *Ann. Surg.*, 1894, XIX, 289.

Digitized by Google

"One (epiphysis) for the small trochanter develops in the thirteenth or fourteenth year and joins the shaft at the eighteenth year." (Pringle's Fractures and Their Treatment.)

"The center for the head appears about the end of the first year, that for the great trochanter about the fourth year and that for the lesser trochanter about the fourteenth year.

"The epiphyses unite with the shaft in the following order and time: Lesser trochanter, seventeenth year; great trochanter, eighteenth year; head, nineteenth year." (Roberts and Kelly's Fractures.)

"Head begins to ossify at one year; ossifies at nineteen. Great trochanter appears at three years; ossifies at eighteen. Lesser trochanter appears at eight years; ossifies at eighteen to nineteen." (Eisendrath, Keen's Surgery.)

"*Development and Changes.* The neck grows as a part of the shaft and receives three epiphyses, one for each trochanter and one for the head, which fits over it like a cap. The latter appears in the second half of the first year, and is pretty conclusive evidence that the age of six months at least has been reached. The epiphysis for the greater trochanter comes in the third year (sometimes some years later), and that for the lesser at a time variously stated as from eight to fourteen years. It is probable that the former is much nearer the mark. The head unites with the shaft at about eighteen, the trochanters somewhat later; probably there are great variations, but all these superior epiphyses should be joined by nineteen, and at twenty the line of union is indistinct or lost." (Piersol's Anatomy.)

"Ossification in the center for the head appears at the end of the first year. Joins about the eighteenth year. Great trochanter appears at the fourth year; joins shaft about the eighteenth year.

"Lesser trochanter appears from the thirteenth to the fourteenth year, joins shaft about the eighteenth year." (Gray's Anatomy.)

Digitized by Google

"No ossification centers are present at birth in the upper end of the femur, the one for the head coming during the first year, for the greater trochanter about the third year, and for the lesser trochanter from the thirteenth to the fourteenth year."[3]

TABLE VI

Author	Epiphysis for Head		Great Trochanter		Lesser Trochanter	
	Appears	Complete Ossification	Appears	Ossifies	Appears	Ossifies
Piersol	Second half of 1st yr.	18th yr.	3rd yr.	19th yr.	8th to 14th yr.	19th yr.
John Poland	10 mos.	19th yr.	4th yr.	18th to 19th yr.	13th yr.	18th yr.
Gray	End of 1st yr.	18th yr.	4th yr.	18th yr.	13th to 14th yr.	18th yr.
Kreuscher	During 1st yr.		3rd yr.		13th to 14th yr.	
Morris	1st yr.	19th yr.	4th yr.	18th yr.	11th yr.	17th yr.
Cunningham	Early part of 1st yr.	18th to 20th yr.	2nd and 3rd yrs.	18th to 19th yr.	12th to 13th yr.	18th yr.
Tubby		18th to 19th yr.		18th yr.		17th yr.
Mears		20th yr.				
Bradford		18th yr.				
Eisendrath	1st yr.	19th yr.	3rd yr.	18th yr.	8th yr.	18th to 19th yr.
Roberts and Kelly	1st yr.	19th yr.	4th yr.	18th yr.	14th yr.	17th yr.
Isidore Cohn	Second half of 1st yr.	15th to 16th yr.	5th yr.	15th to 16th yr.	9th to 11th yr.	15th to 16th yr.

[3] Kreuscher, P. H. A study of the development of the epiphysis. *Surg., Gynec. & Obst.*, 1918, XXVII, v, 480.

Digitized by Google

"The epiphysis for the head appears during the first year and fuses with the shaft during the nineteenth year. The great trochanter appears in the fourth year and unites with the shaft at eighteen years. The lesser trochanter appears in the eleventh year and unites with the shaft at seventeen years." (Morris' Anatomy.)

"The head appears during the early part of the first year and fuses with the shaft from the eighteenth to the twentieth year. The great trochanter appears between the second and third year, and fuses with the shaft between the eighteenth and nineteenth year. The lesser trochanter appears between the twelfth and thirteenth years and fuses with the shaft during the eighteenth year." (Cunningham's Anatomy.)

Observations Based on a Study of Roentgenograms of the Normal Hip

I. There are three epiphyses for the upper end of the femur: one each for the head, greater and lesser trochanter.

II. None of the epiphyses is ossified at birth.

III. The epiphysis for the head begins to ossify during the second half of the first year.

IV. At one year the epiphysis for the head is represented by an elliptical shadow which is widely separated from the upper end of the shaft.

V. The neck of the femur is an upward growth from the shaft, which during the second year of life forms an obtuse angular expansion of the upper portion of the shaft.

VI. At the junction of the neck and shaft on the inner aspect of the femur there is a bony prominence which is probably the lesser trochanter. This prominence is definitely a portion of the shaft and not a separate epiphysis. A separate scale-like epiphysis appears over this bony prominence, at times, about the ninth year. This is completely ossified and united with the shaft during the sixteenth year.

Digitized by Google

VII. On the outer aspect of the femur, at the junction of the neck and shaft, there is a prominence which is part of the shaft. A separate epiphysis for the great trochanter begins to ossify over this prominence at five years of age.

VIII. The epiphysis for the head, which appears during the first year as an elliptical mass, rapidly increases in size, and when the third year is reached this epiphysis is large enough to cover entirely the upper end of the shaft. An epiphyseal line persists until the fifteenth year; beyond this there is complete ossification and union with the shaft.

IX. The great trochanter appears at about five years of age. Ossification is complete and union has taken place between fifteen and sixteen years.

Digitized by Google

Interpretation of Individual Roentgenograms of the Normal Hip (Plates xxvi–xxxvii)

Digitized by Google

PLATE XXVI

Seven Weeks (Fig. 133). The upper end of the shaft of the femur is represented by a broad expansion. There is no evidence of ossification within any of the epiphyses.

On the inner side of the shaft there is a small tubercle, which may represent the lesser trochanter. This tubercle is part of the shaft of the femur.

Four Months (Fig. 134). There is no evidence of an epiphysis for the upper end of the femur. The upper end of the shaft is represented by a broad, apparently flat surface.

Digitized by Google

FIG. 133. SIX WEEKS.

FIG. 134. FOUR MONTHS.

Digitized by Google

PLATE XXVII

Eleven Months (Fig. 134A). The epiphysis for the head is present. There is a wide separation between the epiphysis and the upper end of the shaft.

At the base of the neck there are prominences on the lateral and mesial aspects of the shaft.

One Year (Fig. 135). One epiphysis is evident, that for the head of the femur. This is represented by a round mass, separated by a wide margin from the shaft.

Digitized by Google

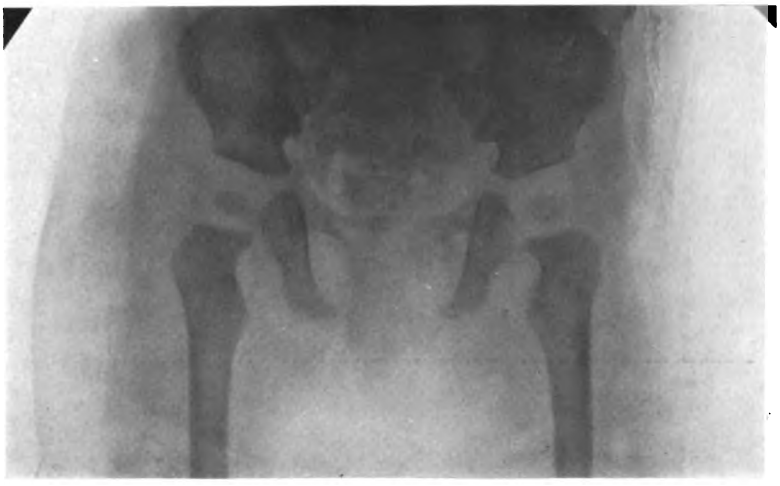


FIG. 134A. ELEVEN MONTHS.

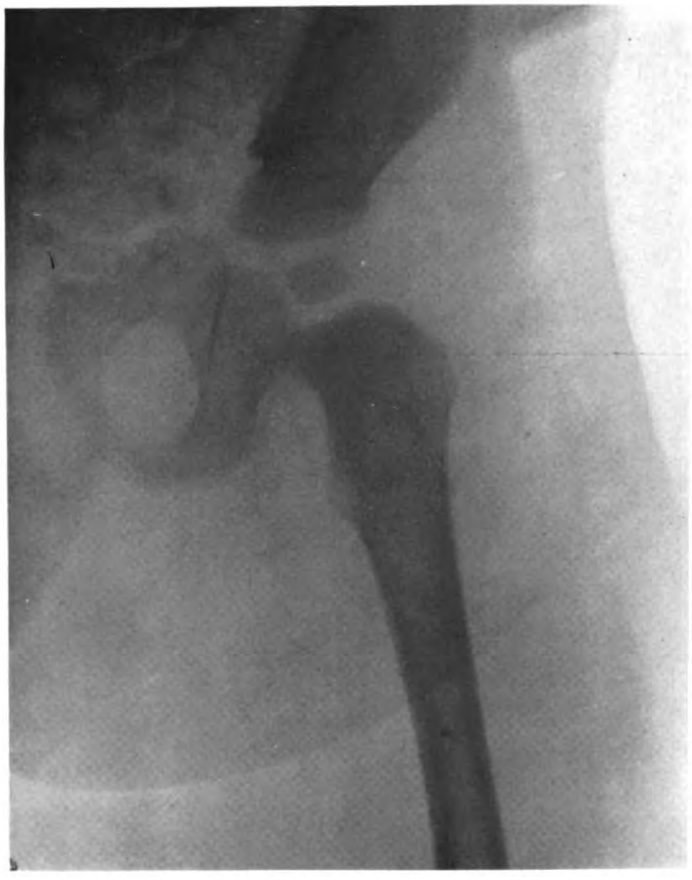


FIG. 135. ONE YEAR.

Digitized by Google

PLATE XXVIII

Two Years (Fig. 136). The epiphysis for the head of the femur is an elliptical mass, separated by a rather wide margin from the upper end of the diaphysis. At this stage, we note a well-marked obtuse angle formed by an outgrowth from the shaft. This probably is the beginning of the neck of the femur. The tubercle mentioned on the inner aspect of the femur, noted at seven weeks, has increased.

Three Years (Fig. 137). There is only one epiphysis present, that for the head of the femur. This epiphysis covers two-thirds of the upper end of the shaft. The upward expansion of the shaft corresponding to the neck is about twice the length of the neck at two years.

Four Years (Fig. 138). The epiphysis for the head of the femur occupies almost the entire wide projecting upper end of the neck. There is, however, a well-marked epiphyseal line.

The tubercle in the region of the lesser trochanter has increased in size. The neck is much wider at its base than at the epiphyseal line, and bony prominences mark the lateral and mesial aspects of the junction of the neck and shaft.

Five Years and Four Months (Fig. 139). The epiphysis for the head of the femur has ossified sufficiently to occupy the upper end of the neck; the epiphyseal line is still well marked.

The epiphysis for the greater trochanter has sufficiently ossified by this time to form an elliptical mass at the junction of the neck and the shaft.

Digitized by Google

FIG. 136. TWO YEARS.

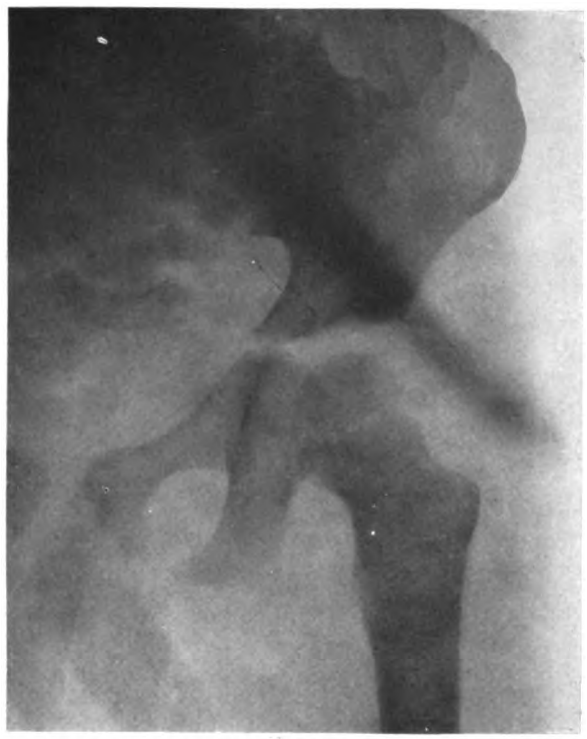


FIG. 137. THREE YEARS.

FIG. 138. FOUR YEARS.

FIG. 139. FIVE YEARS, FOUR MONTHS.

Digitized by Google

PLATE XXIX

Six Years and Six Months (Fig. 140). There are two epiphyses present, one for the head and one for the great trochanter; each is ossifying at a rate corresponding to the growth of the femur.

Seven Years and Five Months (Fig. 141). The head has ossified in proportion with the shaft. The epiphysis for the great trochanter is about twice the size that it was at five years and five months. The lesser trochanter is represented by an outgrowth from the shaft of the femur, and not as a separate epiphysis.

Eight Years (Fig. 142). The epiphysis for the head of the femur now has a broader surface than the upper end of the shaft; the epiphyseal line is present, but it is very narrow. The great trochanter epiphysis has a pyramidal shape. There is evidence of fusion of the component parts of the acetabulum.

No separate epiphysis for the lesser trochanter is evident.

Nine Years (Fig. 143). The epiphysis for the upper end or head of the femur is well developed, but there is a well-marked epiphyseal line between the head and neck. The great trochanter is well developed, but a marked epiphyseal line separates it from the shaft. There is no evidence of a separate epiphysis for the lesser trochanter; there is, however, a protuberance on the inner aspect of the shaft, just below the junction of the head and neck. At this time we note that the acetabulum still shows an incomplete fusion of its component parts.

Digitized by Google

FIG. 140. SIX YEARS, SIX MONTHS.

FIG. 141. SEVEN YEARS, FIVE MONTHS.

FIG. 142. EIGHT YEARS.

FIG. 143. NINE YEARS.

Digitized by Google

PLATE XXX

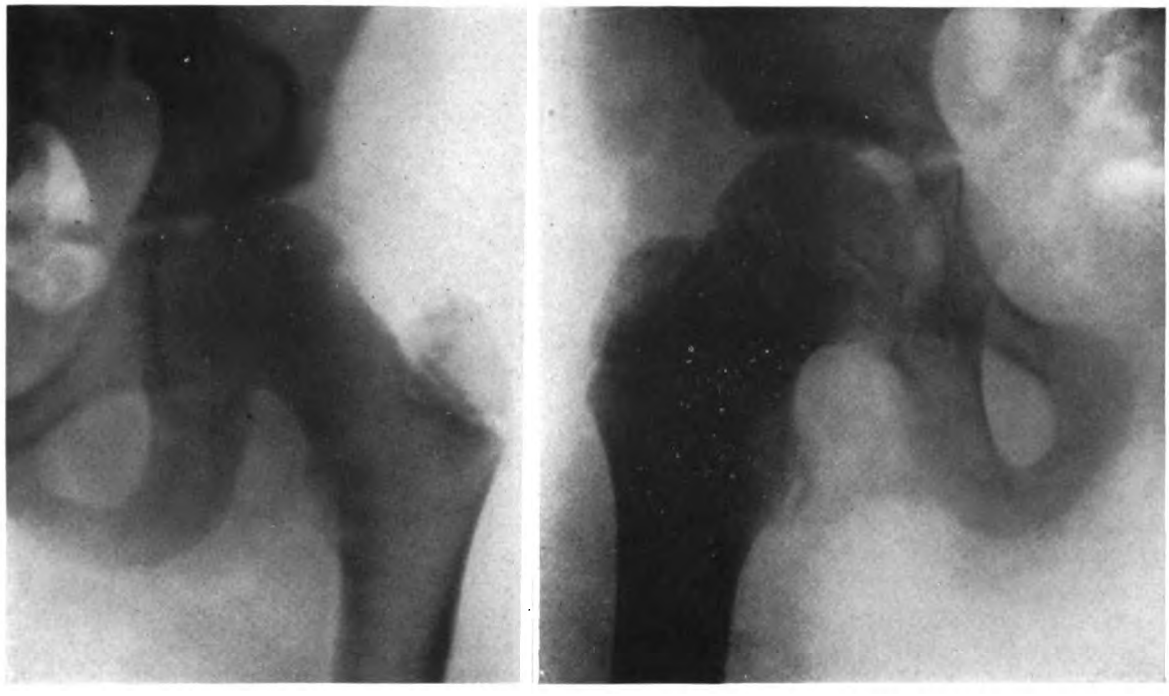
Nine Years (Figs. 144 and 145). There is a well-marked epiphyseal line between the head and neck. A separate epiphysis for the lesser trochanter is seen ossifying in this case.

The two illustrations give the altered appearance of the hip at this age, due to change of position.

Ten Years (Fig. 146). At this time, the normal joint is characterized by a well-developed epiphysis for the head and great trochanter, with a marked epiphyseal line separating the epiphysis from the shaft and lack of fusion between the component parts of the acetabulum.

Ten Years (Fig. 147). Incomplete fusion of the acetabulum. Well-marked epiphyseal line between the head and neck. The epiphyseal line between the great trochanter and the shaft is still present though there is some evidence of bony union. No evidence of a separate epiphysis for the lesser trochanter.

Digitized by Google



FIGS. 144 AND 145. NINE YEARS.

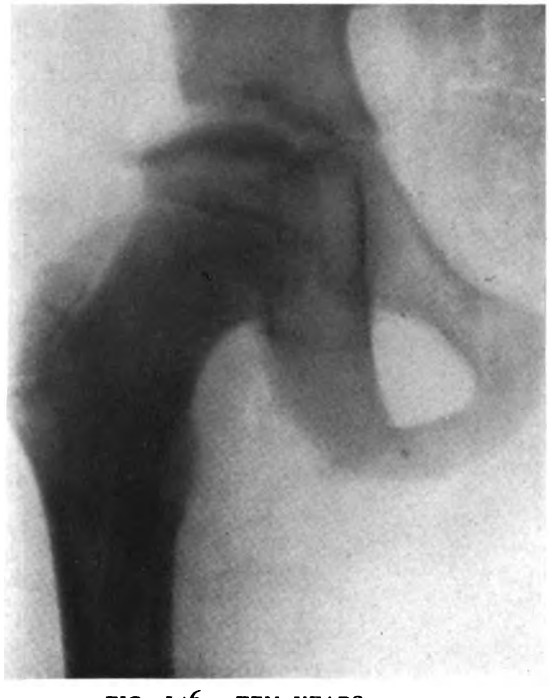


FIG. 146. TEN YEARS.

FIG. 147. TEN YEARS.

Digitized by Google

PLATE XXXI

Ten Years (Fig. 148). The epiphyseal line between the head and neck is still evident. The great trochanter shows some evidence of bony union with the shaft. Incomplete fusion between the various portions of the innominate bone.

Ten Years and Eleven Months (Fig. 149). There is incomplete fusion between the portions of the innominate bone. The epiphyseal line between the head and neck is becoming less evident. The lesser trochanter is evident here as a separate epiphysis.

Eleven Years (Fig. 150). 1. The epiphyseal line between the head and neck is almost obliterated.

2. The great trochanter seems to be ossifying from two separate centers.

3. Lack of fusion in the acetabulum. Union between the great trochanter and the shaft is proceeding from above downward.

Eleven Years and Four Months (Fig. 151). Incomplete fusion of the innominate bones. There is a well-marked epiphyseal line between the head and neck. There is partial fusion of the great trochanter and the shaft. The lesser trochanter, as a part of the shaft, is well marked.

Digitized by Google

FIG. 148. TEN YEARS.

FIG. 149. TEN YEARS, ELEVEN MONTHS.

FIG. 150. ELEVEN YEARS.

FIG. 151. ELEVEN YEARS, FOUR MONTHS.

Digitized by Google

PLATE XXXII

Twelve Years and Three Months (Fig. 152). 1. There is incomplete fusion of the component parts of the acetabulum.

2. The head is still separated from the shaft by a distinct epiphyseal line.

3. The great trochanter is well developed but there is still a distinct epiphyseal line.

4. The lesser trochanter is not evident.

Thirteen Years (Fig. 153). 1. Incomplete fusion of the component parts of the acetabulum.

2. The epiphyseal line between the head and neck is indistinct, suggesting the beginning of ossification.

3. Ossification between the great trochanter and the shaft is proceeding from the middle outward.

Thirteen Years (Fig. 154). The epiphyseal lines between the head and the neck and between the great trochanter and the shaft are indistinct. There is a well-marked separate epiphysis for the lesser trochanter.

Thirteen Years and Ten Months (Fig. 155). 1. Complete fusion of the acetabulum.

2. Almost complete ossification of the epiphyseal line between the head and neck.

3. Ossification has proceeded between the great trochanter and the shaft except at the lower portion.

4. There is still a well-marked epiphyseal line between the lesser trochanter and the shaft.

Digitized by Google

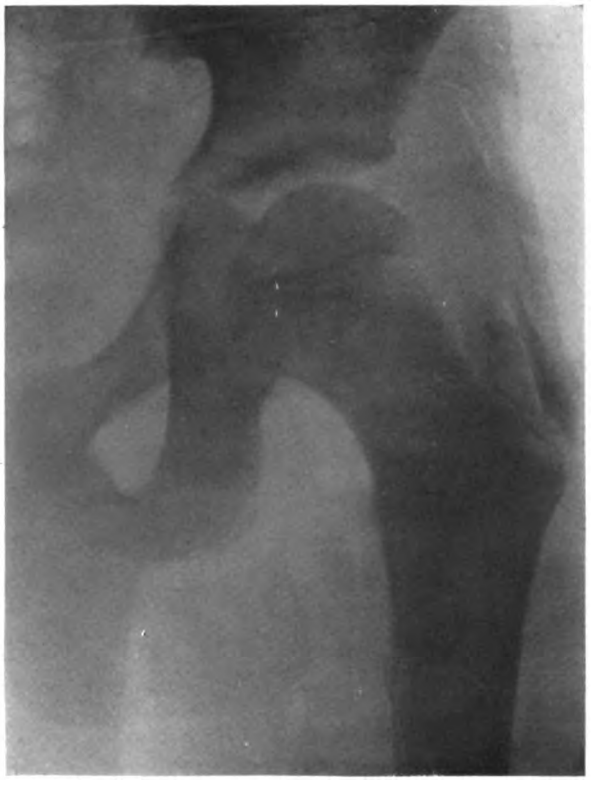


FIG. 152. TWELVE YEARS, THREE MONTHS.

FIG. 153. THIRTEEN YEARS.

FIG. 154. THIRTEEN YEARS.

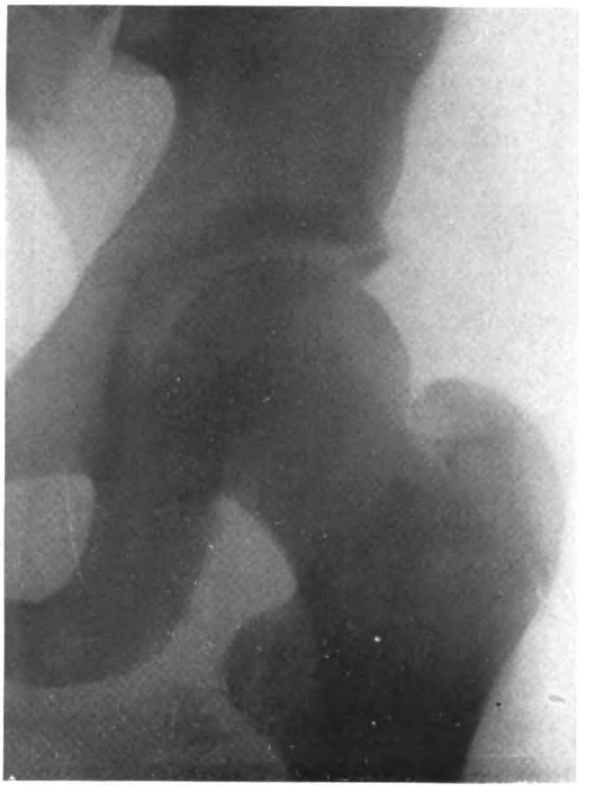


FIG. 155. THIRTEEN YEARS, TEN MONTHS.

Digitized by Google

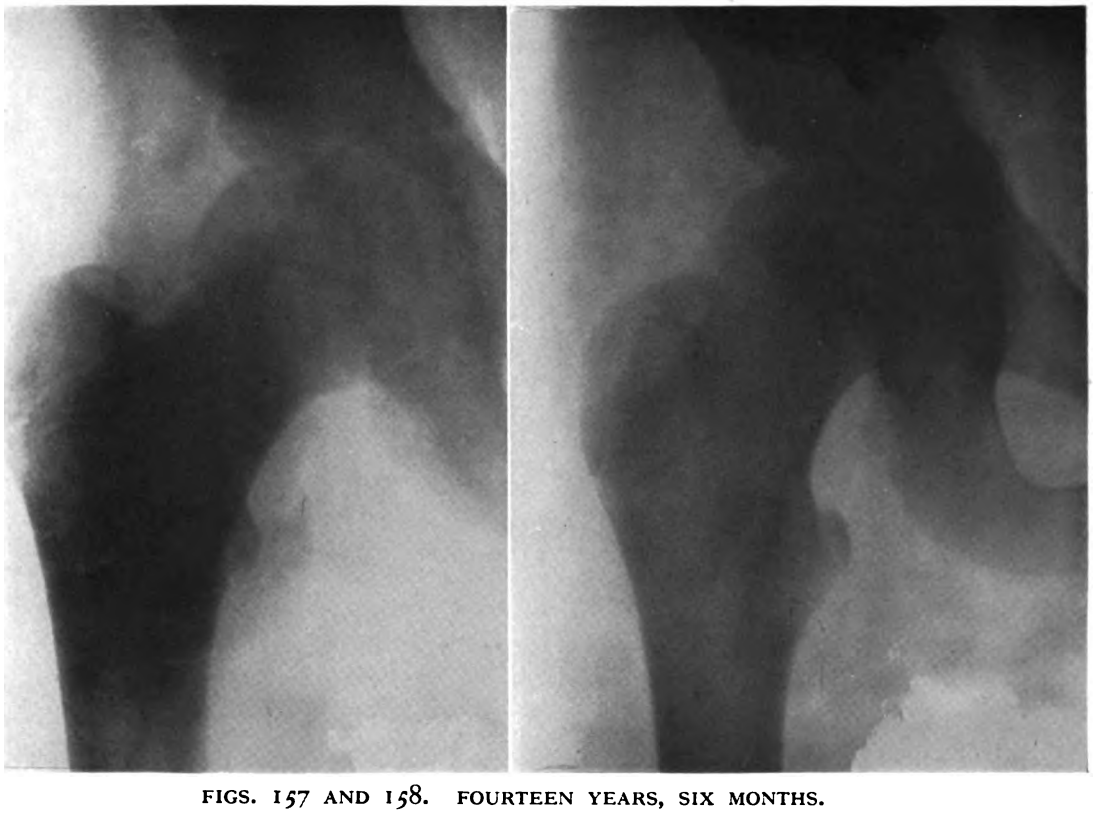
PLATE XXXIII

Fourteen Years and Six Months (Fig. 156). The head of the femur is well developed. The epiphyseal line between the head and the neck is still evident, but very faint. The great trochanter is well developed, union with the shaft being about at its middle, but the epiphyseal line in the upper and lower portions of the great trochanter is still evident. The lesser trochanter is well developed and ossified. There is almost complete ossification of the acetabulum.

Fourteen Years and Six Months (Figs. 157 and 158). The head of the femur is well developed. The epiphyseal line between the head and the neck is indistinct. The great trochanter is well developed, union with the shaft being about at its middle, but the epiphyseal line in the upper and lower portions is still evident. The lesser trochanter shows a well-developed separate epiphysis. The two roentgenograms show the lesser trochanter by change of position.

Digitized by Google

FIG. 156. FOURTEEN YEARS, SIX MONTHS.



FIGS. 157 AND 158. FOURTEEN YEARS, SIX MONTHS.

Digitized by Google

PLATE XXXIV

Fourteen Years and Eight Months (Fig. 159). 1. Complete fusion of the acetabulum.

2. Complete ossification of the head and union with the shaft.

3. Complete ossification and union of the great trochanter with the shaft.

4. Incomplete union of the lesser trochanter and the shaft.

Fourteen Years and Ten Months (Fig. 160). 1. Complete fusion of the acetabulum.

2. Complete ossification of the head and union with the shaft.

3. There is a persistent epiphyseal line in the lower portion of the great trochanter.

4. Complete ossification of the lesser trochanter and union with the shaft.

Fifteen Years (Fig. 161). Complete ossification of the great trochanter and bony union of the great trochanter and shaft, except at the lower portion. There is a distinct separate epiphysis for the lesser trochanter. The epiphyseal line between the head and neck is not evident. The acetabulum shows evidence of fusion of its component parts.

Fifteen Years (Fig. 162). Complete ossification of the head and union between the epiphysis for the head and the neck. Complete ossification of the great trochanter, but union with the shaft is incomplete at the lower portion. Complete ossification of the acetabulum.

Digitized by Google

FIG. 159. FOURTEEN YEARS, EIGHT MONTHS.

FIG. 160. FOURTEEN YEARS, TEN MONTHS.

FIG. 161. FIFTEEN YEARS.

FIG. 162. FIFTEEN YEARS.

Digitized by Google

PLATE XXXV

Fifteen Years (Fig. 163). Complete ossification of the head and neck. The epiphyseal line between the great trochanter is still evident at the lower aspect. The second view of the same case shows that when the thigh is rotated outward, there is evidence of a small separate epiphysis for the lesser trochanter which is completely ossified.

Fifteen Years (Fig. 163A). Complete ossification of all the epiphyses and union with the shaft.

Fifteen Years and Four Months (Fig. 164). Complete ossification of the head of the femur and bony union between the head and neck. Complete ossification between the great trochanter and the shaft. Complete ossification of the acetabulum.

Fifteen Years and Nine Months (Fig. 165). Complete ossification of the epiphyses and union with the diaphysis.

Digitized by Google

FIGS. 163 AND 163A. FIFTEEN YEARS.

FIG. 164. FIFTEEN YEARS, FOUR MONTHS.

FIG. 165. FIFTEEN YEARS, NINE MONTHS.

Digitized by Google

PLATE XXXVI

Sixteen Years (Fig. 166). Complete ossification and union between the respective epiphyses and the diaphysis.

Eighteen Years (Fig. 167). Complete ossification and union of all of the component parts of the femur.

Nineteen Years (Fig. 168). Complete ossification and union of all the epiphyses to the shaft.

Nineteen Years and Eight Months (Fig. 169). Complete ossification and union of all the epiphyses to the shaft.

Digitized by Google

FIG. 166. SIXTEEN YEARS.

FIG. 167. EIGHTEEN YEARS.

FIG. 168. NINETEEN YEARS.

FIG. 169. NINETEEN YEARS, EIGHT MONTHS.

Digitized by Google

PLATE XXXVII

Twenty Years (Fig. 170). Complete ossification of all of the epiphyses to the shaft.

Digitized by Google

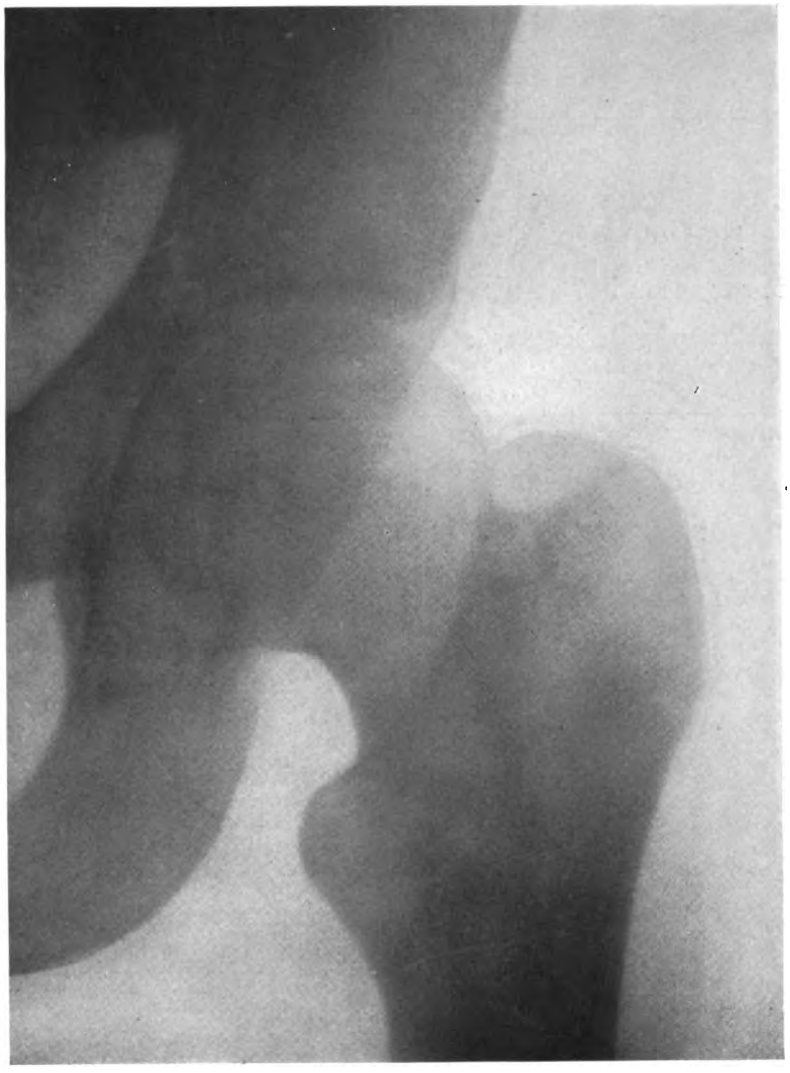


FIG. 170. TWENTY YEARS.

Digitized by Google

Chapter VI

THE NORMAL KNEE

Review of the Literature

John Poland states that "the lower epiphysis of the femur begins to ossify about the second or third week after birth and that union between the epiphysis and diaphysis is complete between the twentieth and twenty-third year.

"The upper epiphysis of the tibia appears the 'second week after birth' and union of the diaphysis and epiphysis takes place from the 'twenty-first to the twenty-second year.'

"The upper epiphysis of the fibula appears during the 'fourth year' and union takes place between the 'twentieth and twenty-second year.'"

Jonathan Hutchinson may fairly be expected to express the best thought of his time on the subject. In a lecture[1] before the Royal College of Surgeons in 1894 he stated in regard to the lower epiphysis of the femur: "There is no epiphysis of so much practical importance as the lower epiphysis of the femur. Theoretically, we might expect a separation to occur beyond the *twentieth year*. The epiphysis includes the whole articular surface, and its separation must imply injury to the synovial membrane." Hutchinson further calls attention to several valuable points which should be kept in mind by a surgeon dealing with this joint in the young—that the adductor tubercle is at the upper limit of the epiphysis, and that both heads of the gastrocnemius are attached to the epiphysis.

"One (center) for the lower extremity (femur) appears shortly before birth and fuses with the diaphysis at about the twentieth year.

[1] Hutchinson, J. The treatment of injuries of the lower end of the humerus, *Brit. M. J.*, Lond., 1894, II, 965.

Digitized by Google

"In the tibia the upper epiphysis, from which both the tuberosities and the tubercle are developed, begins to ossify at birth and joins the diaphysis at the twenty-first to the twenty-fourth year.

"There is sometimes a separate center for the anterior tubercle which shows at the eleventh or twelfth year.

"In the fibula, the upper epiphysis begins to ossify at about the fourth year and joins the shaft at the twenty-second to the twenty-fourth year." (Pringle's Fractures and Their Treatment.)

Reference to texts on the subject of the appearance, development and ossification of the epiphyses of the knee is of interest. Quotations from some of the foremost texts will be of service.

"Ossification appears within the lower epiphysis of the femur during the ninth month of fetal life. Ossification within this center is not complete until the twentieth year.

"*Patella: Development.* By a single center which makes its appearance at about the third year. More rarely this bone develops by two centers placed side by side. Ossification is complete about the age of puberty.

"*Tibia.* The center for the upper epiphysis appears before or shortly after birth; it is flattened in form and has a tongue-shaped process in front which forms the tubercle. The upper epiphysis of the tibia joins the shaft about the twentieth year." (Gray's Anatomy.)

"*Femur.* The lower epiphysis is joined by twenty and often sooner.

"*Patella.* The bone is not fully formed until after puberty—perhaps not before eighteen.

"*Tibia.* The epiphysis for the upper end appears usually during the last month of pregnancy.

"The upper epiphysis extends farther down in front to form the tubercle, which may have a separate nucleus. According to Rambaud and Ranault

Digitized by Google

this is the usual occurrence, appearing from eight to fourteen years and quickly joining the epiphysis.

"The upper epiphysis joins the shaft at about nineteen or twenty." (Piersol's Anatomy.)

"The lower epiphysis of the femur, the largest epiphysis of the body, appears shortly before birth, attains a good size by two years of age and unites to the diaphysis at from the twentieth to the twenty-third year.

"The epiphysis of the upper end of the tibia appears at about the first year and unites to the shaft at the twentieth to the twenty-second year." (Scudder's Treatment of Fractures.)

Cotton in his work on "Joint Fractures and Dislocations" avoids mentioning the age of ossification of the epiphysis of the lower end of the femur and the upper end of the tibia.

"The lower epiphysis of the femur includes the entire articular surface of the lower end of the bone. It is the largest epiphysis of the body, and unites with the diaphysis from the twentieth to the twenty-first year.

"The tubercle and upper epiphysis of the tibia ossifies from a single center, and unites with the diaphysis from the twenty-first to the twenty-second year. The tubercle at first is cartilaginous, and ossification extends downward from the epiphysis as a long tongue-shaped projection." (Roberts and Kelly's Fractures.)

Observations Based on a Study of Roentgenograms of the Normal Knee

From a review of the literature, it would seem that all are agreed that the lower epiphysis of the femur appears before birth, but there does not seem to be a unanimity of opinion as to the time of complete ossification and union with the shaft. Such statements as "about the twentieth year or

Digitized by Google

TABLE VII

Author	Lower Epiphysis Femur Appears	Ossified Completely
Hutchinson		Beyond 20th yr.
Pringle	Shortly before birth	About 20th yr.
Gray	9 mo. fetal life	20th yr.
Pierson		20th yr. or sooner
Scudder	Shortly before birth	20th to 23rd yr.
Cotton		No mention is made of age of ossification
Roberts and Kelly		20th to 21st yr.
Stimson		The epiphysis may not unite with the shaft before the 25th yr.
John Poland	2nd or 3rd wk. after birth	20th to 23rd yr.
Isidore Cohn	Present at birth	19th yr.

TABLE VIII

Author	Upper Epiphysis of Tibia Appears	Completely Ossified
Pringle	Begins to ossify at birth	21st to 24th yr.
Gray	Before or shortly after birth	About 20th yr.
Piersol	During last month of pregnancy	About 19th or 20th yr.
Scudder	About the 1st yr.	20th to 21st yr.
Poland	2nd wk. after birth	21st to 22nd yr.
Isidore Cohn	Present at birth	19th yr.

Digitized by Google

sooner, twentieth to twenty-third year, and up to the twenty-fifth year" are found in the anatomies and texts commonly referred to.

From our observations, it seems justifiable to state that complete ossification and union of the lower epiphysis of the femur with the shaft takes place between the eighteenth and nineteenth year constantly. In some instances, complete ossification and union with the shaft has taken place during the fourteenth year (Fig. 195) and again a similar condition has been noted during the fifteenth year (Fig. 199).

It may be argued that development occurs sooner in tropical and semi-tropical climates; this cannot be disputed, but it would prove interesting if our observations would be either verified or corrected for other climatic conditions.

There is a decided divergence of opinion expressed in the literature relative to the time of complete union of the upper epiphysis of the tibia. From Table 11 and quotations in the portion of the chapter dealing with this phase of the question, it can be seen that union is supposed to take place at any time between the nineteenth and twenty-fourth years.

In this series of observations, the epiphyseal line cannot be made out after eighteen years and eleven months (Figs. 205 and 206).

Aside from this fact, the upper epiphysis of the tibia presents several interesting phenomena which are worthy of more than passing comment. It should be noted that normally the upper epiphysis of the tibia is in the same perpendicular planes as the lower epiphysis of the femur, and any deviation laterally should arouse suspicion that there is a displacement of one of the two.

Second and most important, the tubercle of the tibia is a downward projection of the upper epiphysis of the tibia, which makes its appearance about the eleventh year. At times the projection seems widely separated from the shaft. This may give rise to the opinion that there is a fracture of the tubercle of the tibia, or "spur" formation. The latter interpretation is

Digitized by Google

often made by a roentgenologist (Figs. 196 and 198). At times, the tubercle seems to develop from two separate centers of ossification, thus simulating a fracture within the tubercle itself (Fig. 198). The tubercle is completely ossified to the shaft by the nineteenth year.

The patella, according to Gray, is completely ossified "about the age of puberty." The time of its appearance is given by Gray as "about the third year."

Piersol states that the patella is "not fully formed until after puberty and probably not until the eighteenth year." The patella is noted in this study for the first time during the fifth year (Fig. 179). It makes its appearance just opposite the epiphyseal line of the lower end of the femur.

The patella presents the most variable appearance of any structure about the knee (Figs. 179 and 181). At times, the patella seems to ossify through two centers within cartilage (Fig. 183). The development is progressive, but its relative position is unchanged, that is, its middle is opposite the original site of the epiphyseal line. At about fourteen years, the patella seems to have reached its full bony development—"seems," because it is difficult to say what the ultimate size will be in a particular case. It can be asserted that by this time it possesses the contour, and, relative to the surrounding structures, a full development of the bone.

The upper epiphysis of the fibula is not evident before the fifth year. At this time, it is represented by a small rounded center of ossification superimposed on the diaphysis of the fibula. In some instances, it has become completely ossified by the fifteenth year (Fig. 199). This union is not constant until the end of the eighteenth year (Figs. 203 and 204).

This epiphysis presents neither an unusual nor an interesting feature.

Digitized by Google

SUMMARY

At birth the lower epiphysis of the femur and the upper epiphysis of the tibia are present.

These epiphyses attain the size of half the width of their respective diaphyses at one year.

During the first four years, no other epiphyses are evident, roentgenographically.

At five years and four months (Figs. 178 and 179) ossification has proceeded to such an extent in the lower end of the femur and the upper end of the tibia, that they almost cover their respective diaphyseal ends.

At this age, for the first time, one sees ossification in the upper epiphysis of the fibula and within the patella.

During the next year, the patella increases rapidly in size. It is at this time that we notice the greatest variation in the developing patella. In one instance, six years and six months (Figs. 180 and 181), the patella is about ½ inch in length, and in another, seven years and one month (Figs. 182 and 183), there are two small ossifying shadows within the cartilaginous patella.

At eight years (Figs. 186 and 187), the depressions for the semilunar cartilage and the spines of the tibia are evident roentgenographically.

At ten years (Figs. 188 and 189), there is a close approximation between the respective epiphyses and their diaphyses.

At ten years and eleven months (Figs. 190 and 191), we see the first evidence of the tubercle of the tibia. It is represented by a downward projection from the upper epiphysis of the tibia.

During the eleventh year (eleven years and six months, Figs. 192 and 193) the tubercle increases rapidly in size, and projects forward, being separated by a wide space from the shaft of the tibia. Union between the tubercle and shaft proceeds from above downward, and from before backward (Figs. 196 and 198).

Digitized by Google

During the eighteenth year (eighteen years and éleven months, Figs. 203 and 204) this tubercle is completely ossified and united to the shaft.

In one instance (fourteen years and ten months, Figs. 197 and 198) the tubercle of the tibia seems to be ossifying through two separate centers.

At fifteen years and four months (Figs. 199 and 200) there seems to be complete ossification within the epiphyses and union of the respective epiphyses and their diaphyses.

After the eighteenth year, there seems to be complete ossification of the epiphyses and diaphyses.

Digitized by Google

Digitized by Google

Interpretation of Individual Roentgenograms of the Normal Knee at Various Ages (Plates xxxviii–xlviii)

Digitized by Google

PLATE XXXVIII

Two Days (Fig. 171). There are two epiphyses present, one for the lower end of the femur, and one for the upper end of the tibia. The epiphysis for the lower end of the femur is larger than that for the tibia.

One Year (Fig. 172). At one year of age, there is one epiphysis for the lower end of the femur, and one for the upper end of the tibia. No epiphysis of the upper end of the fibula is apparent. The epiphysis of the lower end of the femur is about two-thirds of the diameter of the diaphysis, and it occupies the midplanes of the lower end of the shaft.

The epiphysis of the upper end of the tibia is about the same size as that of the lower epiphysis of the femur, and is in the same perpendicular planes, roentgenographically.

Digitized by Google

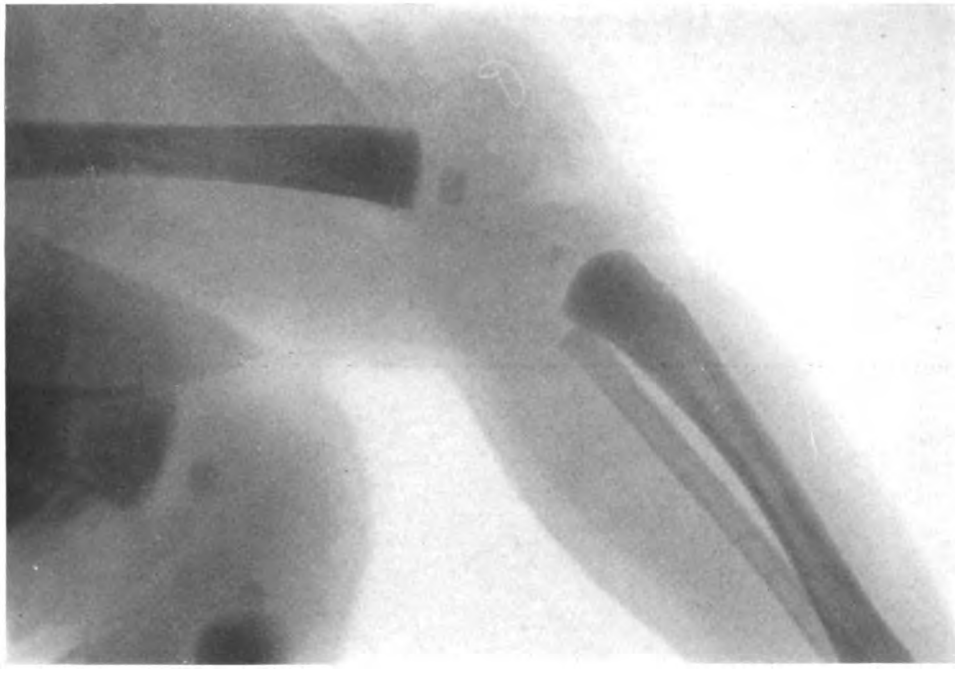


FIG. 171. TWO DAYS.

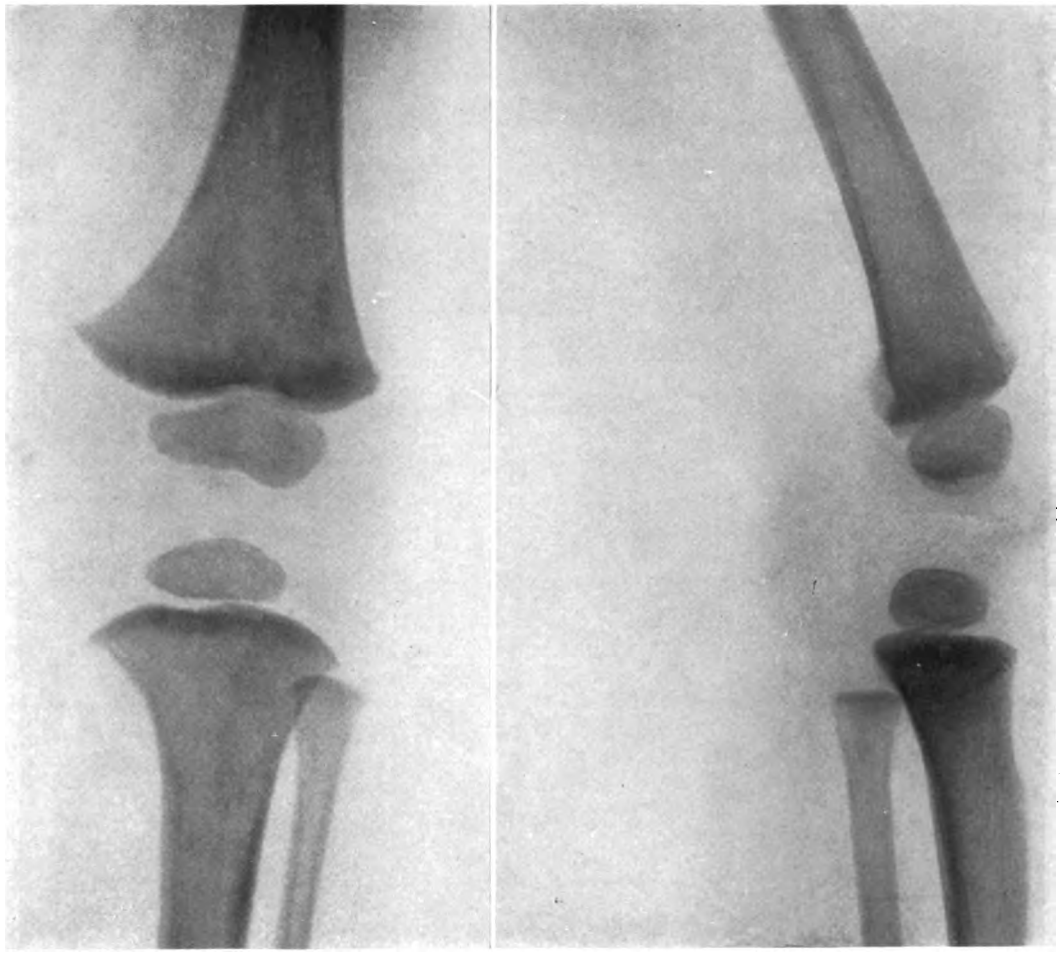
FIG. 172. ONE YEAR.

Digitized by Google

PLATE XXXIX

Two Years (Figs. 173 and 174). The appearance is similar to that of one year of age, except a relative increase in size. A depression for the intercondyloid space is evident.

Digitized by Google



FIGS. 173 AND 174. TWO YEARS.

Digitized by Google

PLATE XL

Three Years (Fig. 175). The epiphyses of the lower end of the femur and upper end of the tibia have increased relatively in the same proportion as the diaphysis. No epiphysis of the upper end of the fibula is evident at this time.

Four Years (Figs. 176 and 177). The lower epiphysis of the femur shows marked evidence of the developing intercondyloid space and occupies three-fourths of the lower aspect of the diaphysis of the femur. There is still no evidence of the epiphysis for the upper end of the fibula. The upper epiphysis of the tibia has not increased in the same ratio as that of the femur.

Digitized by Google

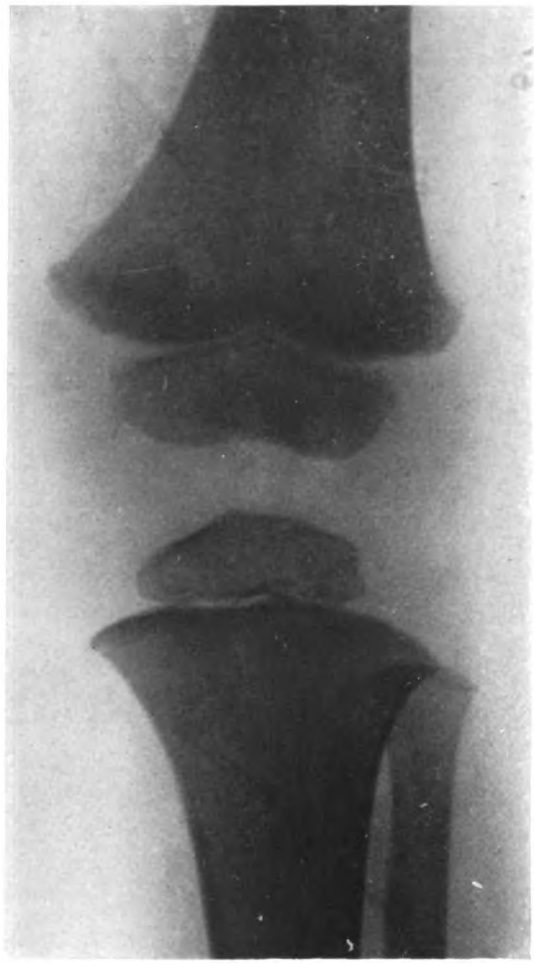
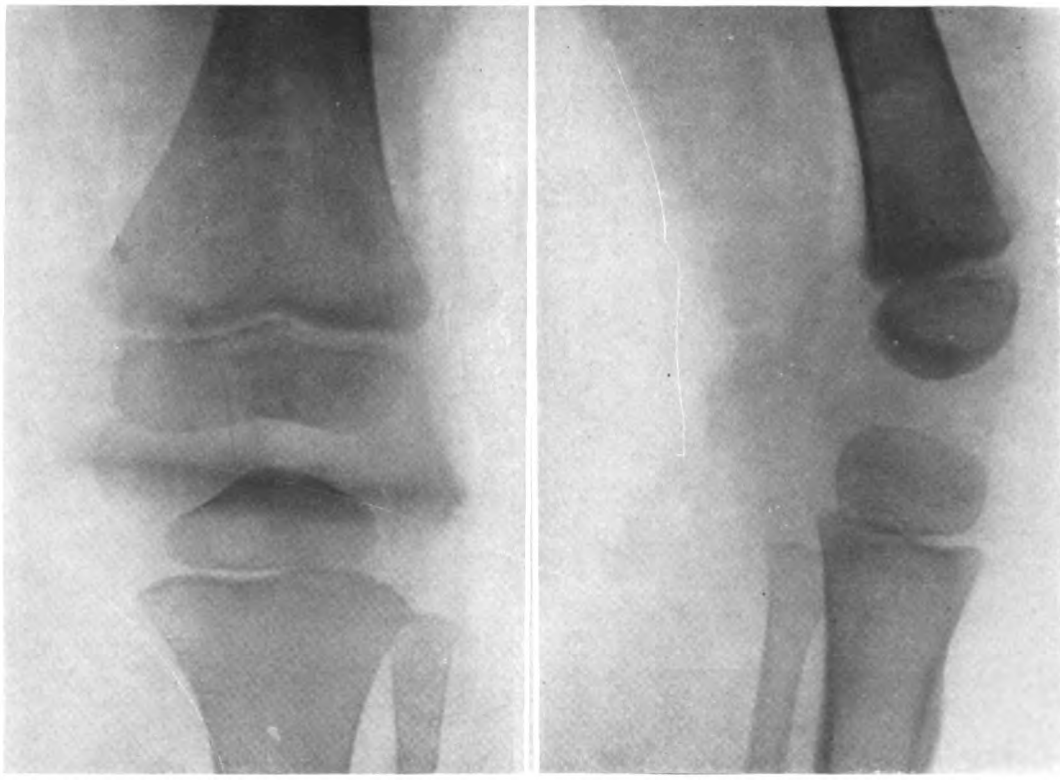


FIG. 175. THREE YEARS.



FIGS. 176 AND 177. FOUR YEARS.

Digitized by Google

PLATE XLI

Five Years and Four Months (Figs. 178 and 179). The lower epiphysis of the femur occupies apparently the lower portion of the femur entirely. A small epiphysis is evident over the upper end of the fibula. Just at the level of the lower epiphyseal line of the femur and anterior to it, we see a small shadow of ossification within the patella.

Six Years and Six Months (Figs. 180 and 181). 1. The lower epiphysis has increased in size, the intercondyloid space is deeper, and the epiphyseal line is not as broad at its middle as at the ends.

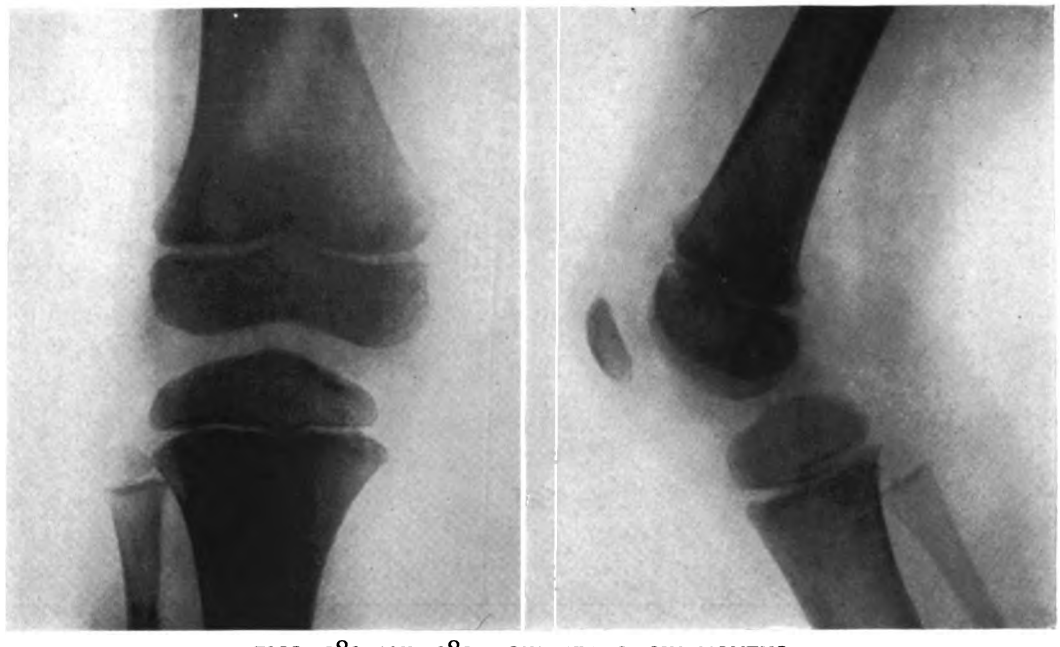
2. The upper epiphysis of the tibia has assumed a pyramidal shape; the apex probably marks the beginning of ossification within the spine.

3. The upper epiphysis of the fibula is now about two-thirds the diameter of the shaft of the bone.

4. The patella is about twice the size noted as that at five years and four months.

Digitized by Google

FIGS. 178 AND 179. FIVE YEARS, FOUR MONTHS.



FIGS. 180 AND 181. SIX YEARS, SIX MONTHS.

Digitized by Google

PLATE XLII

Seven Years and One Month (Figs. 182 and 183). The epiphyses of the tibia and femur are not unlike the previous description (Figs. 180 and 181).

The upper epiphysis of the fibula is represented by a very small ossifying center. The patella presents two small centers of ossification separated widely from one another.

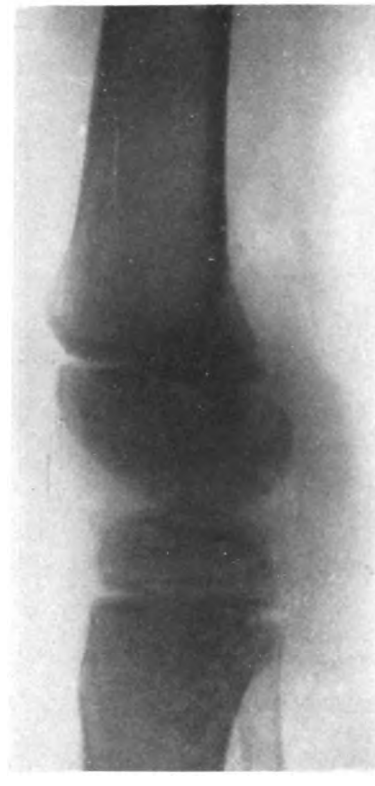
This is probably a delay in development and not an average case.

Seven Years and Five Months (Figs. 184 and 185). All the epiphyses have increased in size; the lower epiphysis of the femur occupies the entire lower portion of the diaphysis.

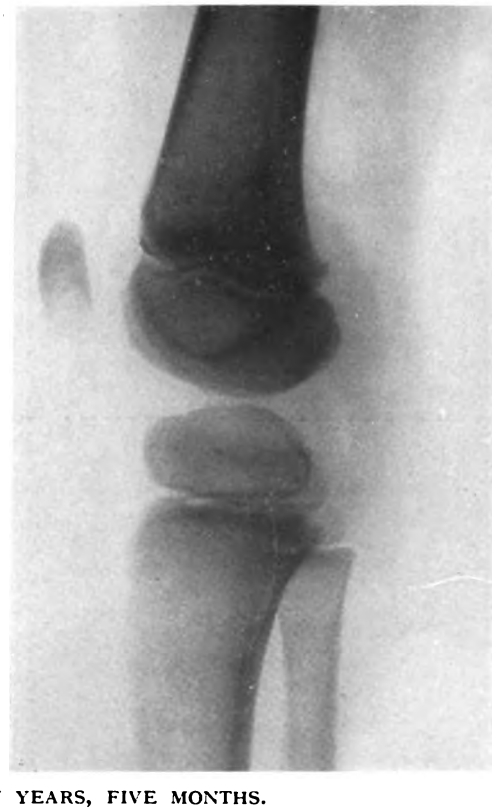
The upper epiphysis of the fibula occupies two-thirds of the diameter of the fibula diaphysis.

The patella has ossified (Fig. 185) to a marked extent as compared to that at seven years. There is evidence of an upward projection within the upper epiphyses of the tibia, differentiating the attachment for the crucial ligament, and also evidence of depressions for the semilunar cartilages.

Digitized by Google



FIGS. 182 AND 183. SEVEN YEARS, ONE MONTH.



FIGS. 184 AND 185. SEVEN YEARS, FIVE MONTHS.

Digitized by Google

PLATE XLIII

Eight Years (Figs. 186 and 187). There is a marked increase in the size of the epiphyses and a closer approximation of the epiphyses and the respective diaphyses. The patella is approximately twice the size of the preceding roentgenograms.

It is interesting to note the amount of development of the patella in the period from six to eight years.

For the first time we begin to see a depression for the semilunar cartilage, and evidence of spines for the insertion of the crucial ligament is evident in the developing upper epiphysis of the tibia (Fig. 187).

Ten Years (Figs. 188 and 189). There is a close approximation between the lower end of the femur and its epiphysis, but no true ossification has taken place between the shaft and the epiphysis.

The depressions for the semilunar cartilages have deepened. There is a proportionate ossification in the upper epiphyses of the fibula and the patella. There is still no evidence of the tubercle of the tibia.

Digitized by Google

FIGS. 186 AND 187. EIGHT YEARS.

FIGS. 188 AND 189. TEN YEARS.

Digitized by Google

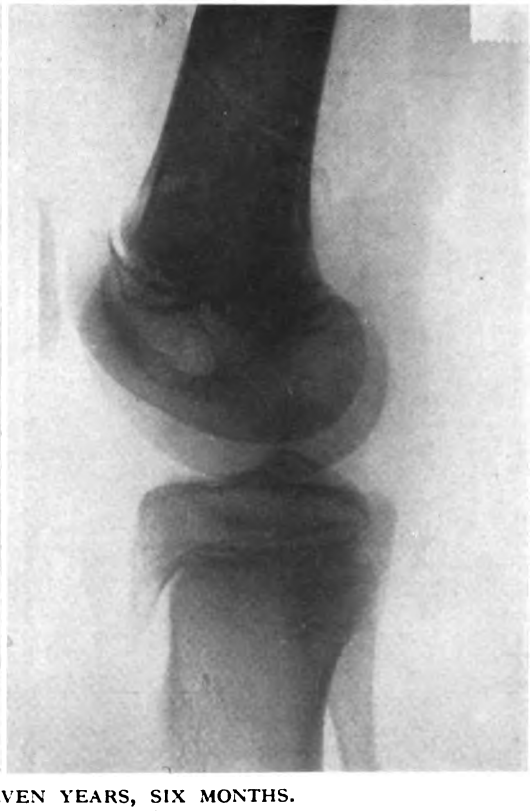
PLATE XLIV

Ten Years and Eleven Months (Figs. 190 and 191). All the epiphyses continue to increase in size. There seems to be a projection downward from the anterior surface of the upper epiphysis of the tibia, this being the first evidence noted of the tubercle of the tibia, and its origin.

Eleven Years and Six Months (Figs. 192 and 193). The epiphyses for the lower end of the femur, the upper end of the tibia and upper portion of the fibula are completely formed, but not united with the shaft. There is a projection downward on the anterior portion of the tibia, separated from the shaft of the tibia for possibly ¼ inch, which is evidence of beginning ossification for the tubercle of the tibia.

Digitized by Google

FIGS. 190 AND 191. TEN YEARS, ELEVEN MONTHS.



FIGS. 192 AND 193. ELEVEN YEARS, SIX MONTHS.

Digitized by Google

PLATE XLV

Twelve Years and Eight Months (Fig. 194). There is a close approximation of the epiphyses to their respective diaphyses but no ossification of the epiphyses and the shafts.

Fourteen Years and Eight Months (Figs. 195 and 196). There is a complete ossification of all the epiphyses and union with the respective diaphyses. The lateral view shows a projection downward from the upper epiphysis of the tibia; on the anterior aspect of the shaft, it is still separated from the shaft, but not as markedly as in preceding ages.

Digitized by Google

FIG. 194. TWELVE YEARS, EIGHT MONTHS.

FIGS. 195 AND 196. FOURTEEN YEARS, EIGHT MONTHS.

Digitized by Google

PLATE XLVI

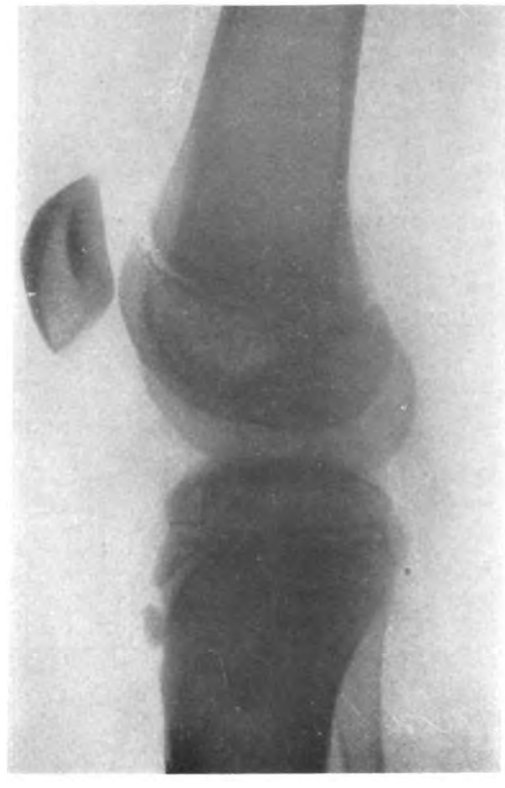
Fourteen Years and Ten Months (Figs. 197 and 198). 1. The epiphyses are entirely ossified but union with the respective diaphyses is incomplete.

2. The tubercle of the tibia is apparently ossifying through two centers.

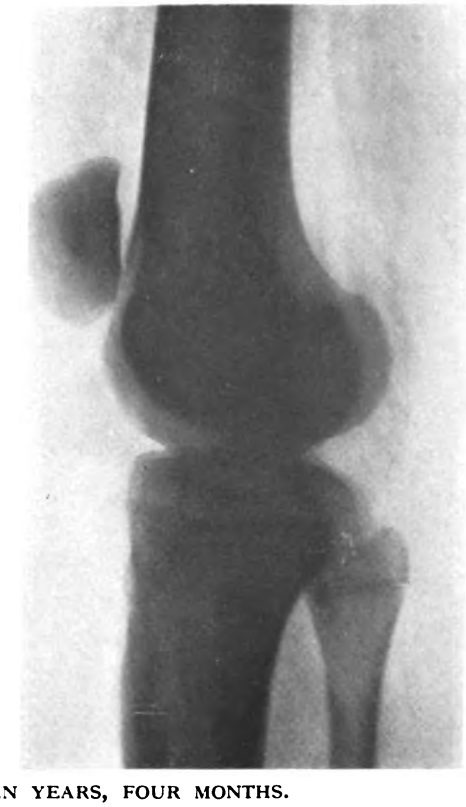
3. The patella is completely ossified.

Fifteen Years and Four Months (Figs. 199 and 200). The epiphyses are completely ossified but there is apparently a line of demarcation between the epiphyses and the shafts.

Digitized by Google



FIGS. 197 AND 198. FOURTEEN YEARS, TEN MONTHS.



FIGS. 199 AND 200. FIFTEEN YEARS, FOUR MONTHS.

Digitized by Google

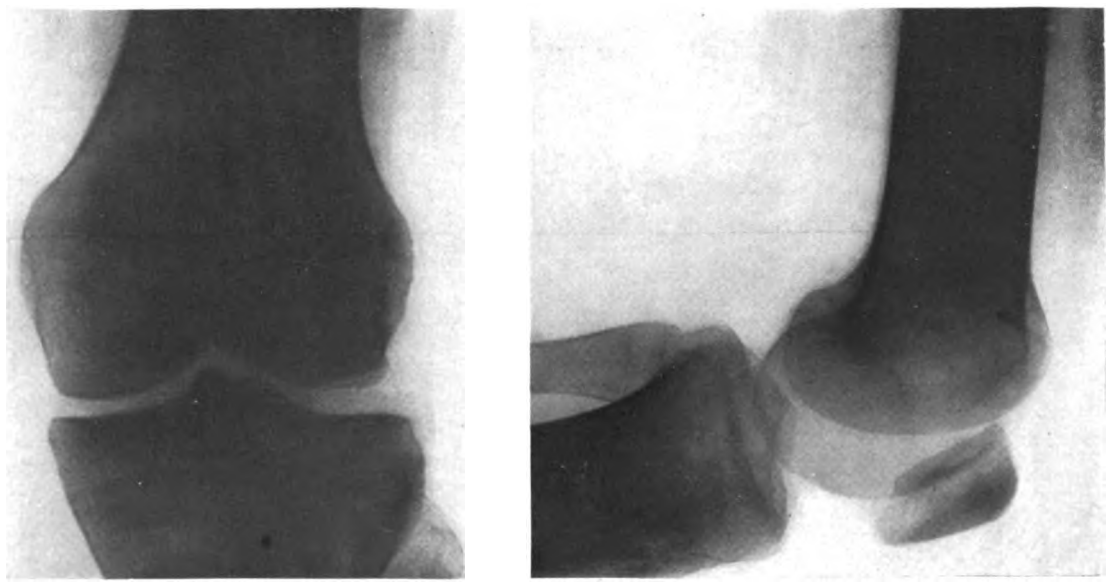
PLATE XLVII

Sixteen Years and Eight Months (Figs. 201 and 202). The epiphyseal lines are present. The tubercle of the tibia is almost completely ossified.

Eighteen Years and Eleven Months (Figs. 203 and 204). Complete ossification of all epiphyses and union of the epiphyses and the shafts.

Digitized by Google

FIGS. 201 AND 202. SIXTEEN YEARS, EIGHT MONTHS.



FIGS. 203 AND 204. EIGHTEEN YEARS, ELEVEN MONTHS.

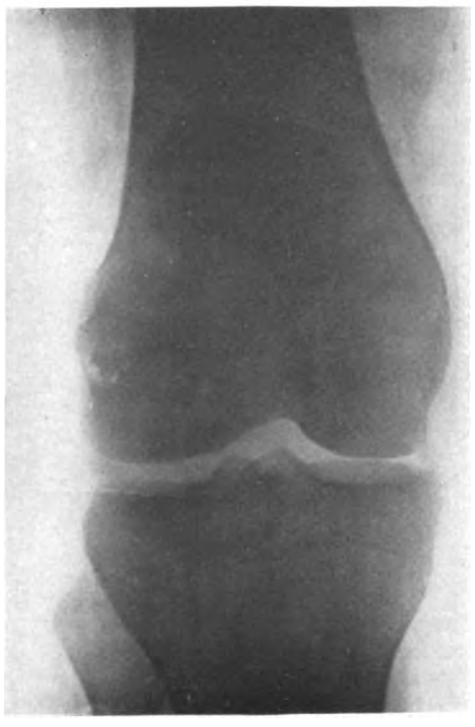
Digitized by Google

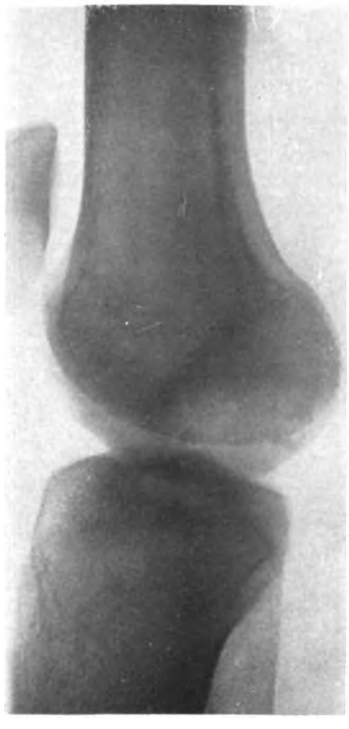
PLATE XLVIII

Twenty Years (Figs. 205 and 206). Complete ossification of all epiphyses and union with the respective shafts.

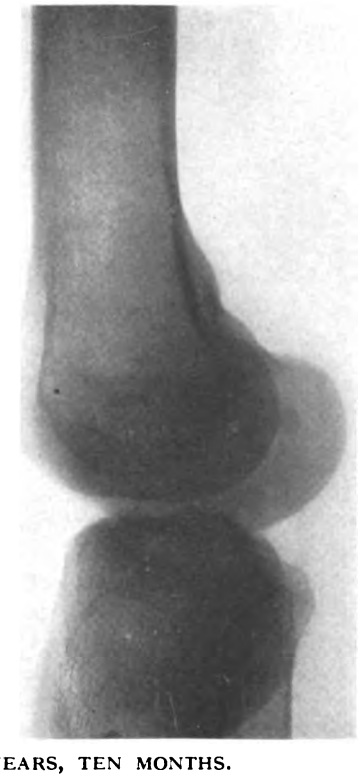
Twenty-One Years and Ten Months (Figs. 207 and 208). Similar to the roentgenograms of twenty years.

Digitized by Google





FIGS. 205 AND 206. TWENTY YEARS.



FIGS. 207 AND 208. TWENTY-ONE YEARS, TEN MONTHS.

Digitized by Google

Chapter VII

THE NORMAL ANKLE

Review of the Literature

This review includes the statements given by various authorities with reference to the lower epiphyses of the tibia, fibula, tarsal and metatarsal bones, and the phalanges.

TIBIA

The lower epiphysis of the tibia begins to ossify at the eighteenth month after birth and ossification and union are completed by the eighteenth year. (Poland's Skiagraphic Atlas.)

"The lower epiphysis of the tibia appears at one and a half years, and fuses with the shaft about the eighteenth year." (Cunningham's Anatomy.)

"*Development.* One in the lower appearing in the second half-year. The lower end joins the shaft at about eighteen." (Piersol's Anatomy.)

"The center for the lower epiphysis appears in the second year. The lower epiphysis joins the shaft at about eighteen." (Gray's Anatomy.)

"The center for the lower epiphysis ossifies about the beginning of the second year; it unites with the shaft about the eighteenth year." (Roberts and Kelly's Fractures.)

"The epiphysis of the lower end appears about the second year and unites to the diaphysis about the eighteenth or nineteenth year." (Scudder's Treatment of Fractures.)

FIBULA

"The lower epiphysis of the fibula appears at the second year and unites with the diaphysis from the nineteenth to the twenty-first year." (Poland's Skiagraphic Atlas.)

"The lower epiphysis appears in the second year and is probably fused with the shaft about the eighteenth or nineteenth year." (Piersol's Anatomy.)

Digitized by Google

"Appears at the second year, unites about the twentieth year." (Gray's Anatomy.)

"The lower epiphysis of the fibula appears at the second year and fuses with the shaft by the nineteenth year." (Cunningham's Anatomy.)

"The center for the lower epiphysis appears about the second year, and unites with the shaft about the twentieth year." (Roberts and Kelly's Fractures.)

TARSAL BONES

"The tarsal bones are each developed by a single center, excepting the os calcis, which has an epiphysis for its posterior extremity. The centers make their appearance in the following order: os calcis, at the sixth month of fetal life; astragalus, about the seventh month; cuboid, at the ninth month; external cuneiform, during the first year; internal cuneiform in the third year; middle cuneiform and navicular in the fourth year. The epiphysis for the posterior tuberosity of the os calcis appears at the tenth year, and unites with the rest of the bone soon after puberty." (Gray's Anatomy.)

"*Calcaneum* (*os calcis*). *Development.* The chief nucleus is said to appear in the sixth month of fetal life. We have twice seen it earlier, once at about the fourth month. An epiphysis for the back of the bone and the posterior plantar tubercles appears from the seventh to the tenth year. It begins to fuse by fifteen, completing the process in a year or so.

"*Cuboid. Development.* There is but one center, appearing at about birth; in our experience, more often after than before.

"*Astragalus. Development.* The nucleus probably appears at about the seventh month of fetal life.

"*Scaphoid. Development.* It is generally held that the process begins in the fourth or fifth year, but according to Gegenbaur, it begins in the first.

"*Internal Cuneiform. Development.* A center appears in the third year.

Digitized by Google

"*Middle Cuneiform. Development.* One center appears in the fourth year.

"*External Cuneiform. Development.* Ossification begins in the first year." (Piersol's Anatomy.)

"*Anatomy. Os calcis.* The primary nucleus appears in the sixth month of intrauterine life. The epiphysis, for its posterior extremity, begins to be ossified in the sixth to the tenth year and is united to the body of the bone between the thirteenth and twentieth years (girls earlier than boys).

"*Navicular. Ossification.* The nucleus for the navicular appears in the course of the fourth year.

"*Talus. Ossification.* The talus is ossified from one nucleus, occasionally from two. The principal center for this bone appears in the middle of the cartilaginous talus at the seventh month of intrauterine life." (Morris' Anatomy.)

"The os calcis develops by a single center, which appears about the sixth month of fetal life, but the ossific center for the epiphysis of the os calcis appears only at the ninth year. The astragalus appears in the seventh month, cuboid in the ninth month, external cuneiform in the first year, internal cuneiform in the third year, mid-cuneiform and scaphoid in the fourth year."[1]

METATARSALS

"Each metatarsal has two centers.

"The primary center appears in the eighth intrauterine week, the other appears in the third year. Consolidation from the fourteenth to the twenty-first year." (Morris' Anatomy.)

"*Development.* Centers for the shafts of the metatarsals appear towards the end of the third month of fetal life. A proximal epiphysis for the first

[1] Kreuscher, P. H. A study of the development of the epiphysis. *Surg., Gynec. & Obst.*, 1918, xxvii, v, 480.

Digitized by Google

TABLE IX

Author	Lower Epiphysis Tibia		Lower Epiphysis Fibula	
	Appears	Complete Ossification	Appears	Complete Ossification
John Poland	18th mo.	18th yr.	2nd yr.	19th to 21st yr.
Gray	In the 2nd yr.	18th yr.	2nd yr.	20th yr.
Cunningham	18th mo.	18th yr.	2nd yr.	19th yr.
Piersol	2nd half yr.	18th yr.	In the 2nd yr.	18th or 19th yr.
Roberts and Kelly	Beginning of 2nd yr.	18th yr.	2nd yr.	20th yr.
Scudder	About 2nd yr.	18th yr.		
Isidore Cohn	About the 5th mo.	18th yr.	13th mo.	18th yr.

TABLE X

Particular Bone	Piersol	Gray	Morris	Kreuscher	Isidore Cohn
Os calcis	6th mo. fetal life	6th mo. fetal life	6th mo. fetal life	6th mo. fetal life	Present at birth
Astragalus	7th mo. fetal life	7th mo. fetal life	7th mo. fetal life	7th mo. fetal life	Present at birth
Cuboid	Birth	9th mo. fetal life		9th mo. fetal life	Present at birth
Scaphoid	4th to 5th yr.	4th yr.	4th yr.		3½ to 4 yrs.
Ex. Cuneiforms	1st yr.	During 1st yr.		1st yr.	3½ yrs.
In. Cuneiforms	3rd yr.	3rd yr.		3rd yr.	3½ yrs.
Mid-cuneiform	4th yr.	4th yr.		4th yr.	3½ to 4 yrs.

Digitized by Google

and distal ones for the others appear in the third year, fusing at about seventeen." (Piersol's Anatomy.)

"The metatarsal bones are each developed by two centers: one for the shaft and one for the distal extremity in the four outer metatarsals; one for the shaft and one for the base in the metatarsal bone of the great toe. Ossification commences in the center of the shaft about the ninth week, and extends toward either extremity. The center in the proximal end of the first metatarsal bone appears about the third year, the center in the distal end of the other bones between the fifth and the eighth year; they become joined between the eighteenth and the twentieth years.

"The phalanges are developed by two centers for each bone: one for the shaft and one for the metatarsal extremity. The center for the shaft appears about the tenth week, that for the epiphysis between the fourth and the tenth years; they join the shaft at about the eighteenth year." (Gray's Anatomy.)

Observations Based on a Study of Roentgenograms of the Normal Ankle

I. At birth there is no evidence of ossification within the lower epiphysis of the tibia or fibula.

II. The lower epiphysis of the tibia appears as a small elliptical shadow about the fifth month. This shadow rapidly increases, almost doubling its size by the end of the first year.

This finding is not at all in accord with most authorities. Reference to the section on literature will convince one of the variation.

III. The lower epiphysis of the fibula begins to ossify in the early part of the second year of life (thirteen months).

IV. There are three tarsal bones in which ossification is evident at birth. During the last part of the first year a fourth tarsal begins to ossify.

V. All the tarsal bones have begun to ossify at three and a half years.

Digitized by Google

VI. The lower epiphysis of the fibula projects downward and is soon on a much lower level than the corresponding epiphysis of the tibia.

During the eighth year, there is a downward projection from this wedge-shaped lower epiphysis for the lower end of the tibia.

By the ninth year, the only marked difference noted is the appearance of ossification within the separate epiphysis for the posterior aspect of the os calcis.

During the fourteenth year occasionally complete ossification has taken place in the lower epiphysis for the tibia and fibula, and union of the respective epiphyses with their diaphyses.

About the fifteenth year the separate epiphysis of the posterior aspect of the os calcis is united with the body of the os calcis.

At times the epiphyseal lines are evident during the sixteenth year.

Complete ossification of all the epiphyseal lines about the ankle has been noted by the eighteenth year. None of the pictures beyond this time shows evidence of any remaining epiphyseal lines.

Digitized by Google

Digitized by Google

Interpretation of Individual Roentgenograms of the Normal Ankles at Various Ages (Plates xlix–lxi)

Digitized by Google

PLATE XLIX

Two Months (Fig. 209). No epiphysis is evident for the lower end of the tibia or fibula. There is sufficient ossification in only three of the tarsal bones to produce a shadow at this stage.

There is no evidence of ossification within the epiphyses of the metatarsals or phalanges.

Five Months (Fig. 210). Ossification has begun in the lower epiphysis of the tibia, which at this time shows a small elliptical shadow, below the middle of the lower end of the diaphysis of the tibia.

There is no evidence of ossification in the lower epiphysis of the fibula.

Only three of the tarsal bones have sufficiently ossified to leave a shadow.

The epiphyses of the metatarsals and phalanges are not evident.

Eleven Months (Fig. 211). The lower epiphysis of the tibia is only slightly larger than the picture taken at five months. There is still no evidence of ossification within the lower epiphysis of the fibula.

Only four of the tarsal bones have sufficiently ossified to leave a shadow.

The metatarsal and phalangeal epiphyses have not yet appeared.

Eleven Months (Fig. 212). Lateral view of the previous figure.

Digitized by Google

FIG. 209. TWO MONTHS.

FIG. 210. FIVE MONTHS.

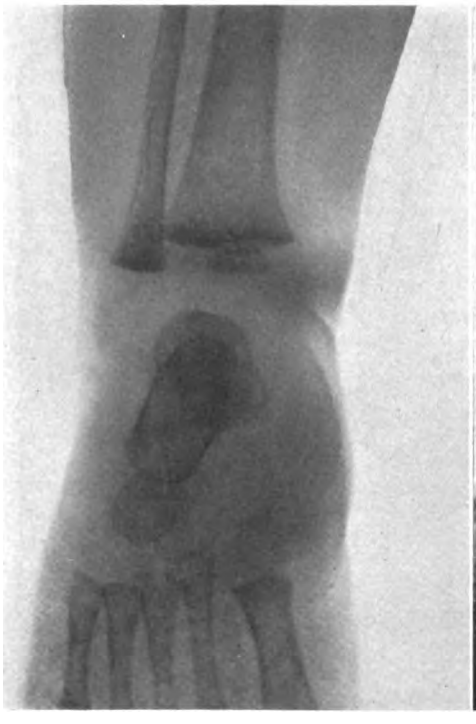


FIG. 211. ELEVEN MONTHS.

FIG. 212. ELEVEN MONTHS.

Digitized by Google

PLATE L

One Year (Fig. 213). 1. The lower epiphysis of the tibia has increased in size.

2. There is no evidence of ossification within the lower epiphysis of the fibula.

3. Four tarsal bones have begun to ossify.

4. The metatarsal and phalangeal epiphyses have not yet appeared.

Thirteen Months (Fig. 214). The lower epiphysis of the fibula shows evidence of ossification.

Digitized by Google

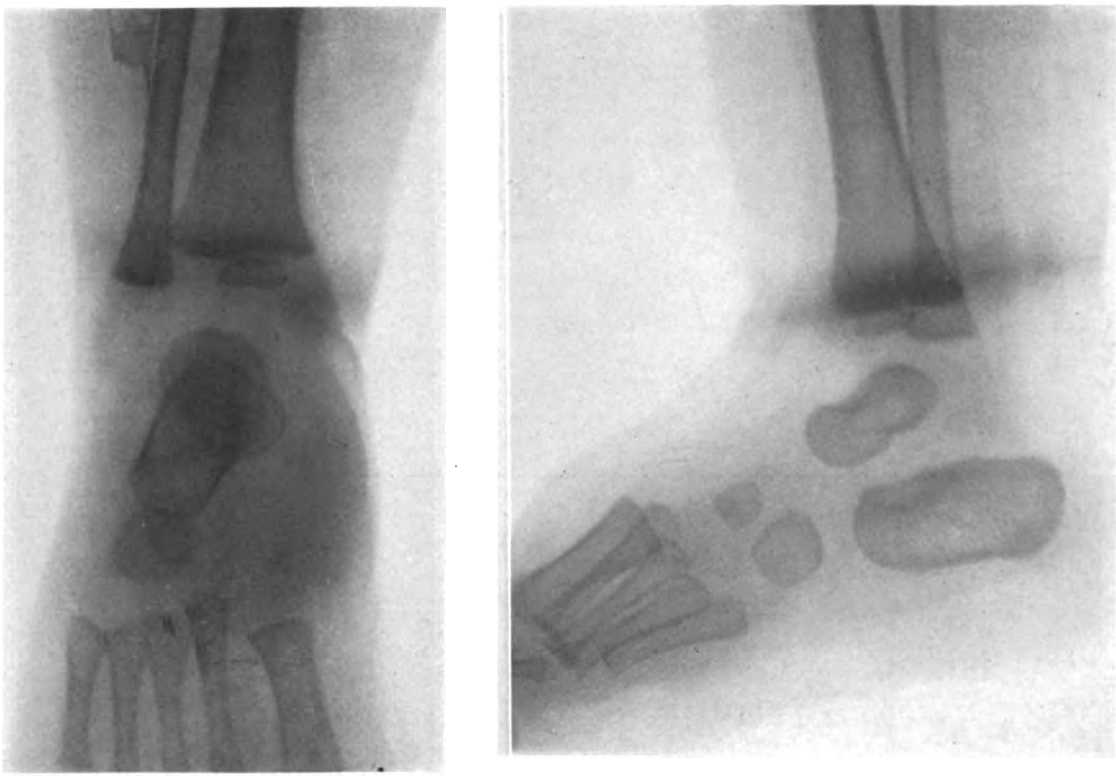


FIG. 213. ONE YEAR.

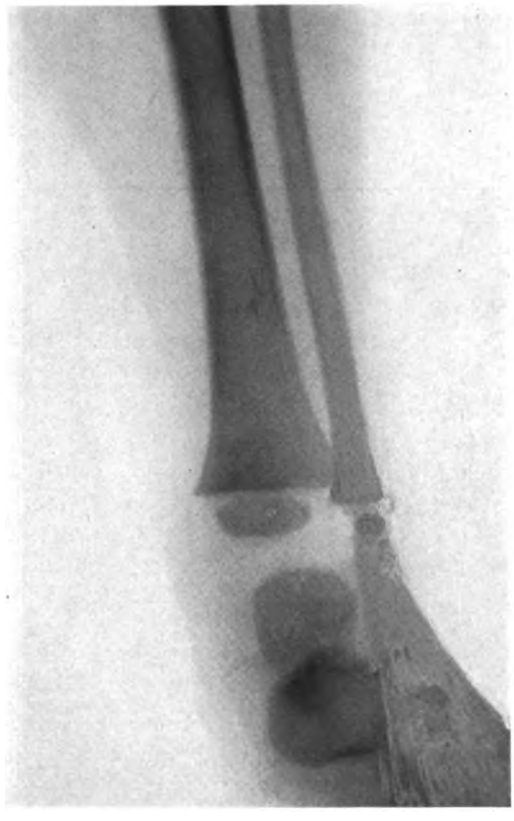


FIG. 214. THIRTEEN MONTHS.

Digitized by Google

PLATE LI

Two Years and Four Months (Fig. 215). 1. The lower epiphysis of the tibia has increased markedly in size, occupying now about one-half of the diameter of the lower end of the diaphysis.

2. The lower epiphysis of the fibula has also increased very markedly. The lower epiphysis of the fibula is now on a lower level than the corresponding epiphysis of the tibia.

3. Four tarsal bones are evident.

4. There is evidence of beginning ossification of the epiphyseal line of the lower end of the tibia.

Two Years and Four Months (Fig. 216). Lateral view of the same case. There is evidence of only four tarsal bones.

Three Years and Six Months (Fig. 217).

Digitized by Google

FIGS. 215 AND 216. TWO YEARS, FOUR MONTHS.

FIG. 217. THREE YEARS, SIX MONTHS.

Digitized by Google

PLATE LII

Four Years (Fig. 218). 1. The lower epiphysis of the tibia covers almost the entire lower end of the diaphysis.

2. The lower epiphysis of the fibula has increased at a proportionate rate and is now on a much lower level than the corresponding epiphysis of the tibia.

3. There are now seven tarsal bones ossified.

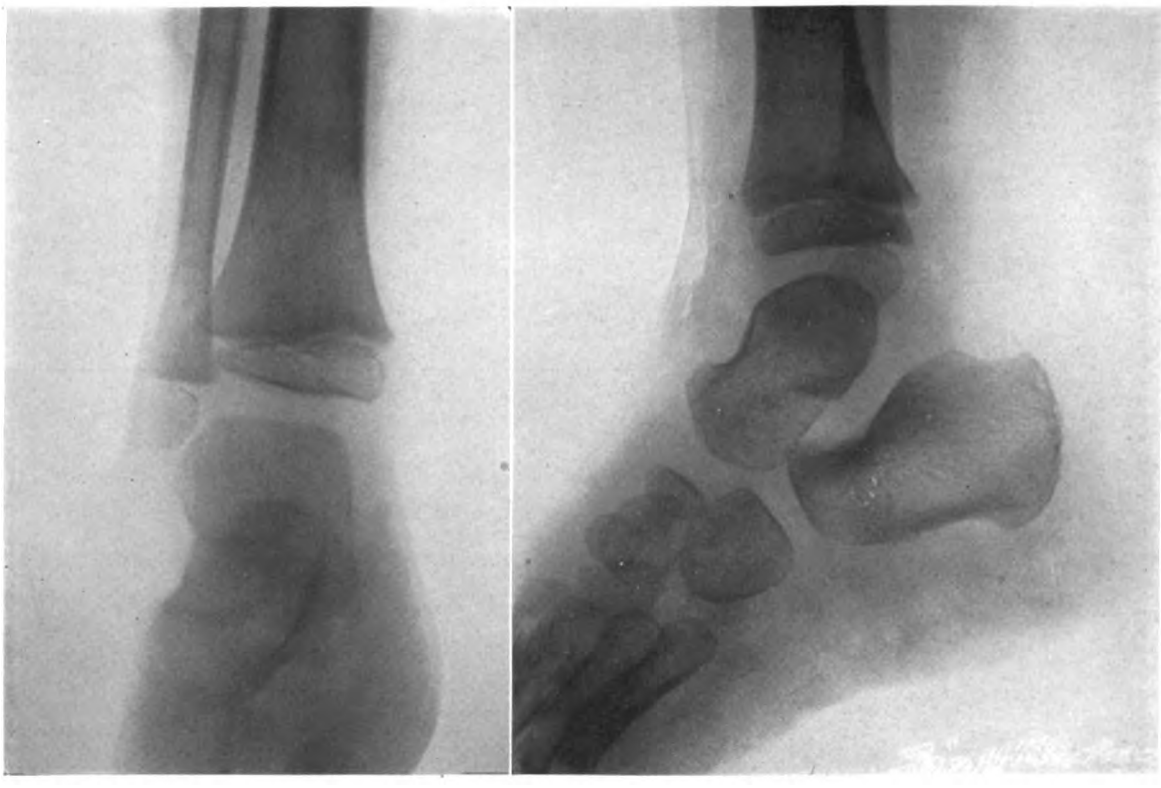
Four Years (Fig. 219). Lateral view of four years, showing ossification within the seven tarsal bones.

Five Years and Four Months (Fig. 220). The epiphyseal line at the lower end of the tibia is smaller and more irregular than at previous ages, thus suggesting beginning ossification between the epiphysis and the diaphysis.

The lower epiphysis of the fibula is on a much lower level than the corresponding tibial epiphysis.

Six Years and Seven Months (Fig. 221). The lower epiphysis of the tibia occupies the entire diameter of the diaphysis. Ossification has proceeded to a great extent on the inner aspect. The epiphysis now presents a wedge-shaped appearance. The lower end of the fibula occupies still the entire diameter of the diaphysis and ossification is present to the extent that this epiphysis now presents the appearance of an inverted cone.

Digitized by Google



FIGS. 218 AND 219. FOUR YEARS.

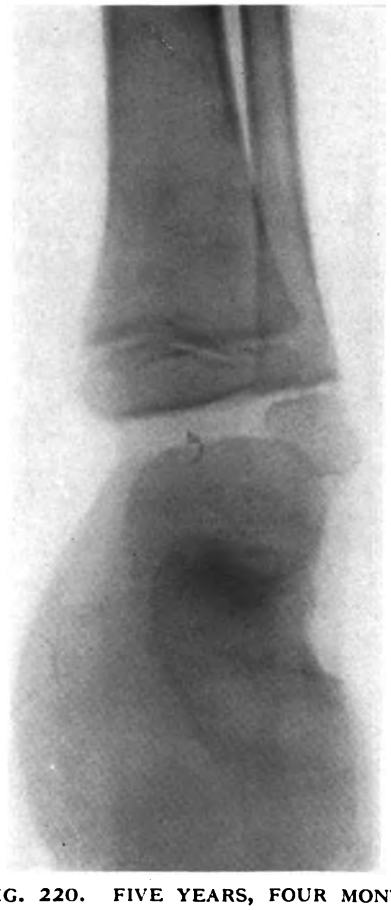


FIG. 220. FIVE YEARS, FOUR MONTHS.

FIG. 221. SIX YEARS, SEVEN MONTHS.

Digitized by Google

PLATE LIII

Eight Years and Six Months (Fig. 222). The lower end of the tibia presents a wedge-shaped appearance, and a downward projection is noted on the inner side of the epiphysis. The lower epiphysis of the fibula is continuing to develop in the inverted cone shape.

Eight Years and Nine Months (Fig. 223). The lower epiphysis of the tibia is wedge-shaped with a projection on the inner side which corresponds to the internal malleolus. The epiphyseal line is well marked and it has an irregular contour. The lower epiphysis of the fibula is conical and is on a much lower plane than the internal malleolus. The epiphysis is widely separated from its shaft. The lateral view (Fig. 224) presents the same appearance, with the addition that the posterior aspect of the os calcis is irregular, but there is yet no evidence of the epiphysis for the posterior portion of the os calcis.

Digitized by Google

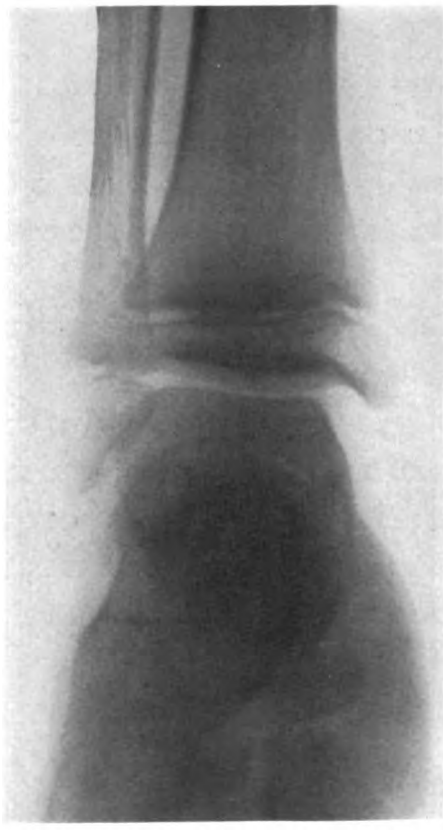


FIG. 222. EIGHT YEARS, SIX MONTHS.

FIGS. 223 AND 224. EIGHT YEARS, NINE MONTHS.

Digitized by Google

PLATE LIV

Nine Years (Fig. 225). The only difference is the appearance of a separate epiphysis for the posterior aspect of the os calcis. All the tarsal bones are well developed.

Ten Years (Fig. 226). The epiphysis for the posterior portion of the os calcis is represented by a "spur-like" process.

Ten Years (Fig. 227). The anteroposterior view shows a well-developed lower epiphysis of the tibia, a wedge-shaped internal malleolus, represented by a downward projection of the inner aspect of the epiphysis.

The lower epiphysis for the fibula is a well-developed, cone-shaped mass the tip being on a lower level than that of the internal malleolus.

The epiphyseal lines are still present.

Digitized by Google

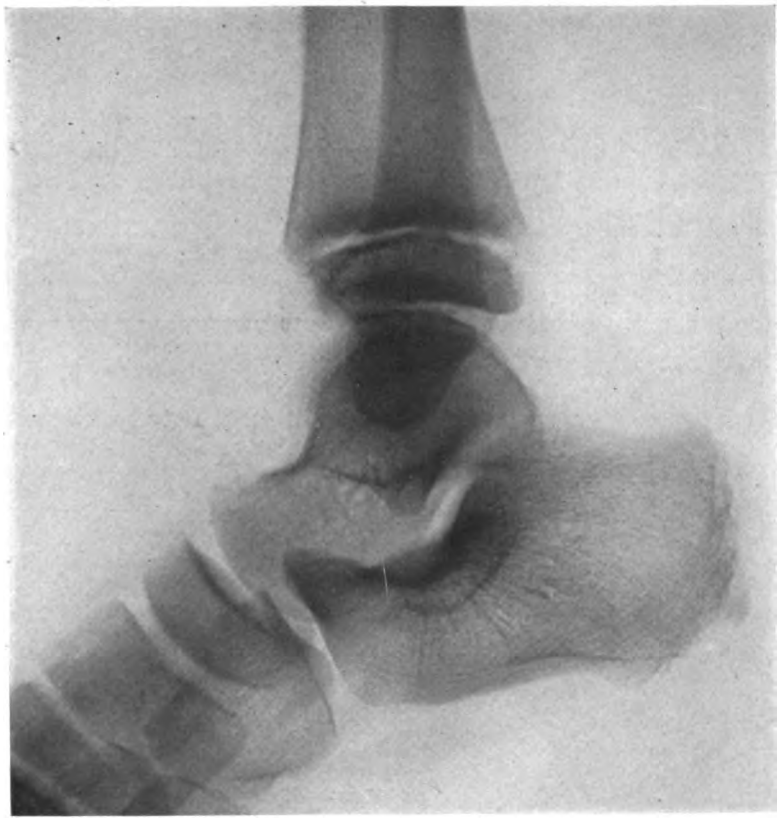
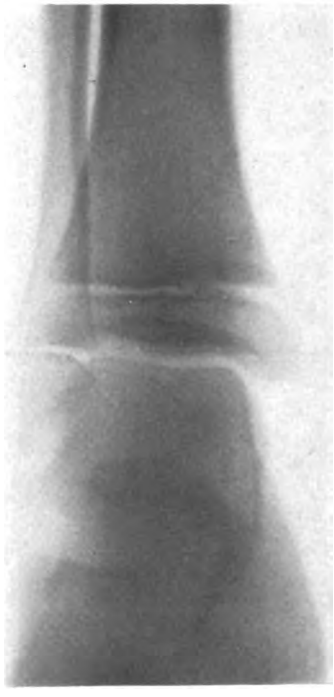


FIG. 225. NINE YEARS.



FIGS. 226 AND 227. TEN YEARS.

Digitized by Google

PLATE LV

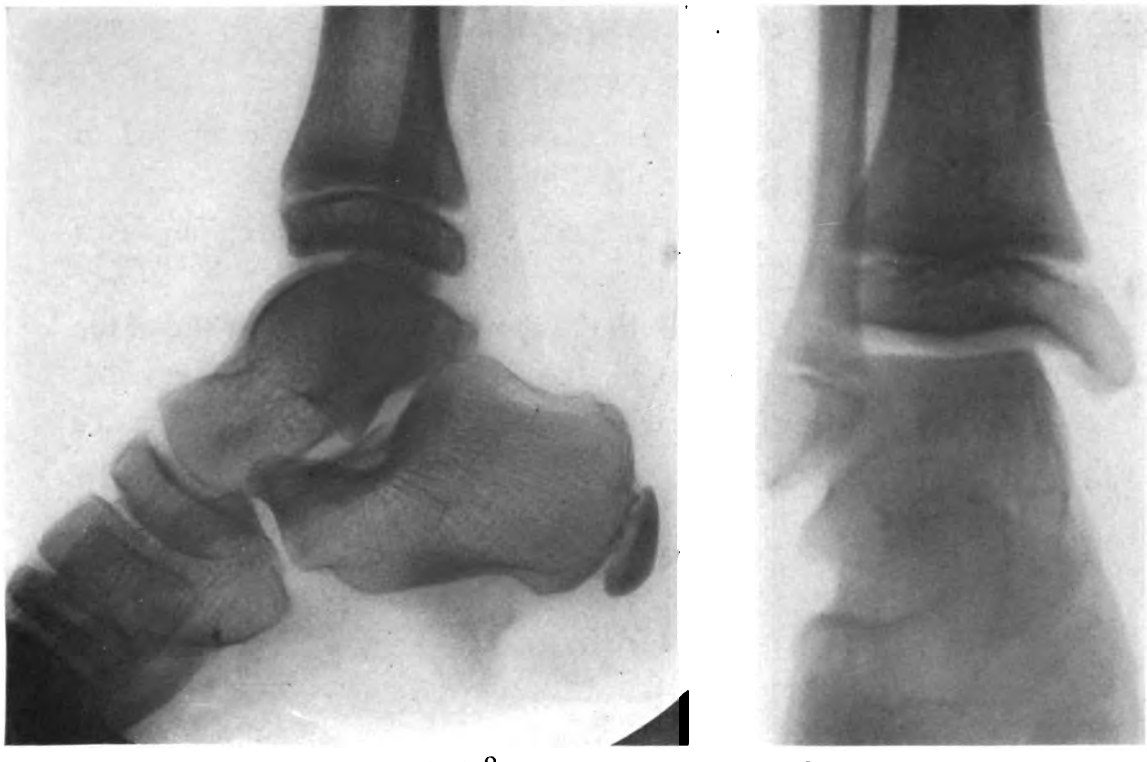
Eleven Years (Fig. 228). The posterior epiphysis of the os calcis is an elliptical mass, about ¾ by ⅛ inches in dimension, and separated by a distinct line from the body of the os calcis.

Eleven Years (Fig. 229). The anteroposterior view at this age shows little change when compared with the previous year.

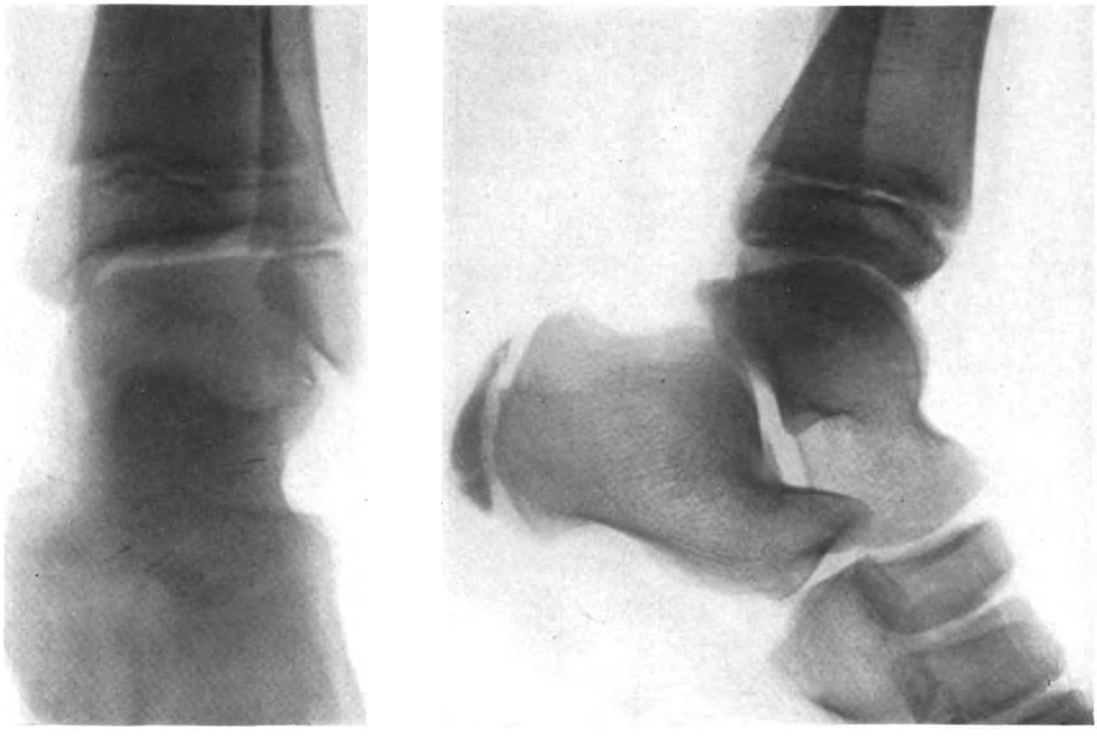
Eleven Years and Two Months (Fig. 230). Anteroposterior view. The entire malleolus shows an increase in size, its appearance being much the same. The epiphyseal line is well marked.

Eleven Years and Two Months (Fig. 231). Lateral view of the same picture. The posterior epiphysis of the os calcis has increased very markedly in size, its appearance being that of a crescentic cap back of the os calcis.

Digitized by Google



FIGS. 228 AND 229. ELEVEN YEARS.



FIGS. 230 AND 231. ELEVEN YEARS, TWO MONTHS.

Digitized by Google

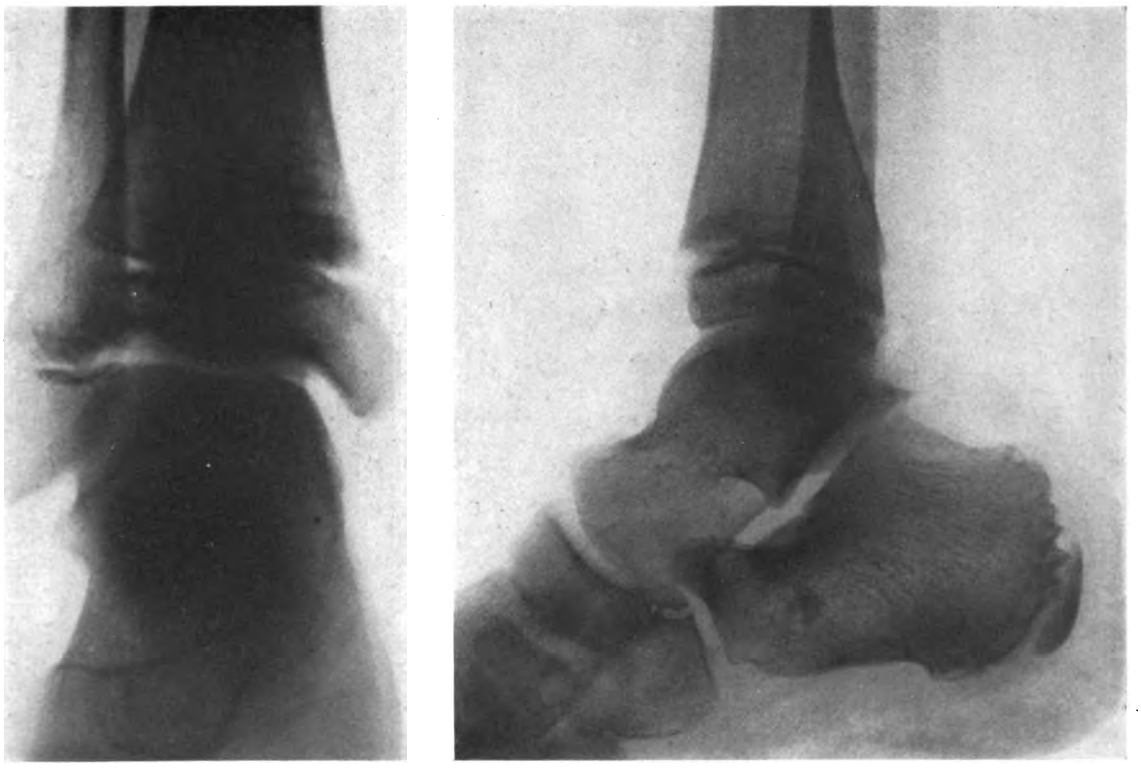
PLATE LVI

Thirteen Years (Fig. 232). Progressive changes when compared to previous figures, but the epiphyseal lines are still well marked.

Thirteen Years (Fig. 233). The lateral view shows a large epiphysis for the posterior portion of the os calcis.

Fourteen Years (Fig. 234). Both the epiphyses for the lower end of the tibia and fibula have increased in size. The epiphyseal lines are well marked, though there is evidence of ossification between each shaft and its respective epiphysis.

Digitized by Google



FIGS. 232 AND 233. THIRTEEN YEARS.

FIG. 234. FOURTEEN YEARS.

Digitized by Google

PLATE LVII

Fourteen Years and Six Months (Fig. 235). Complete ossification of the lower epiphysis of the tibia and fibula, and union of the respective epiphyses with the shaft.

Fourteen Years and Nine Months (Fig. 236). Complete ossification of the respective epiphyses and union between the epiphyses and diaphyses.

Fourteen Years and Nine Months (Fig. 237). Shows complete ossification of the respective epiphyses of tibia and fibula with the shaft, as well as complete ossification of the epiphysis of the posterior portion of the os calcis and union with the body of the os calcis.

Digitized by Google

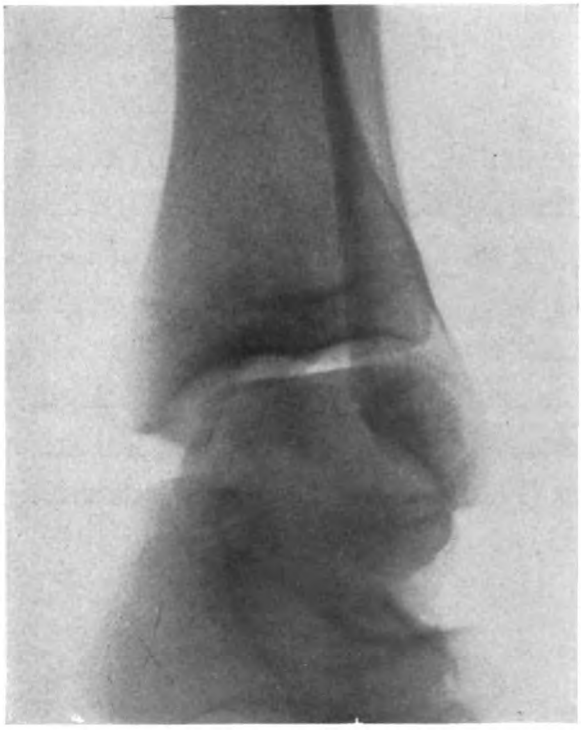


FIG. 235. FOURTEEN YEARS, SIX MONTHS.

FIG. 236. FOURTEEN YEARS, NINE MONTHS.

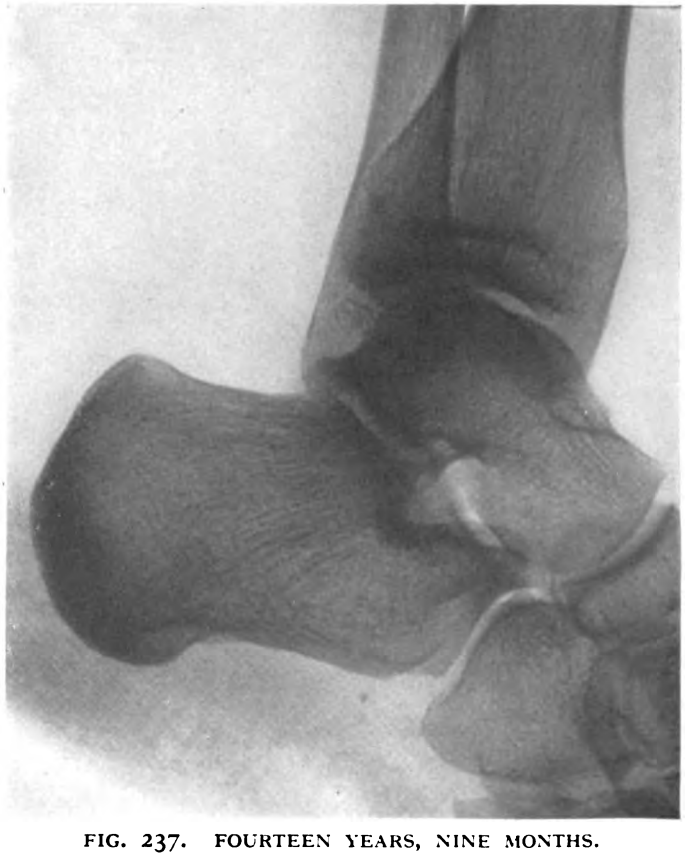


FIG. 237. FOURTEEN YEARS, NINE MONTHS.

Digitized by Google

PLATE LVIII

Fourteen Years and Ten Months (Fig. 238). 1. Complete ossification of the epiphysis of the tibia and fibula, but there is a distinct epiphyseal line.

2. The epiphysis for the posterior portion of the os calcis covers two-thirds of the posterior aspect of the bone. Union with the body of the bone has not taken place.

Fourteen Years and Ten Months (Fig. 239). All the epiphyses are well developed, but there is a persistence of epiphyseal lines.

Fifteen Years (Figs. 240 and 241). See description of Figures 242 and 243.

Digitized by Google

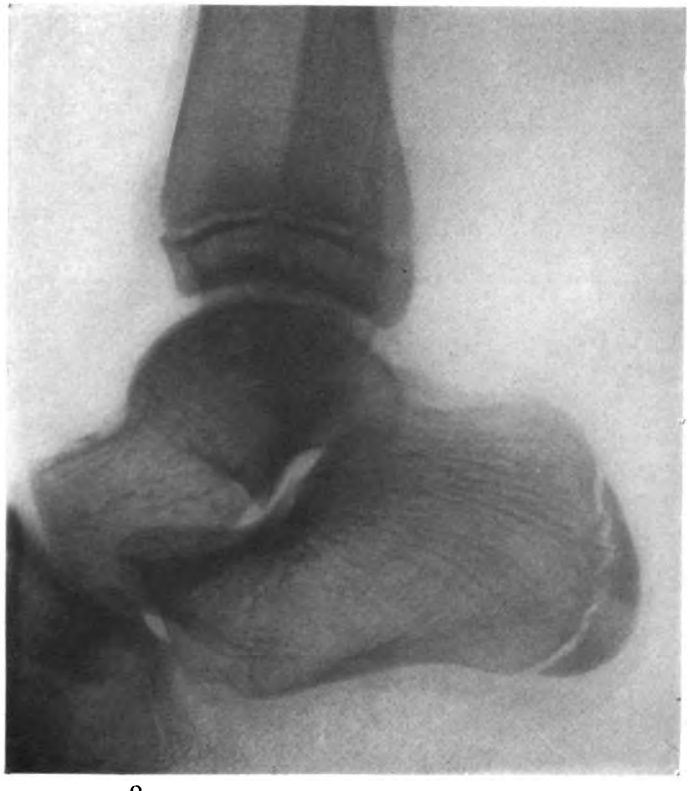


FIG. 238. FOURTEEN YEARS, TEN MONTHS.

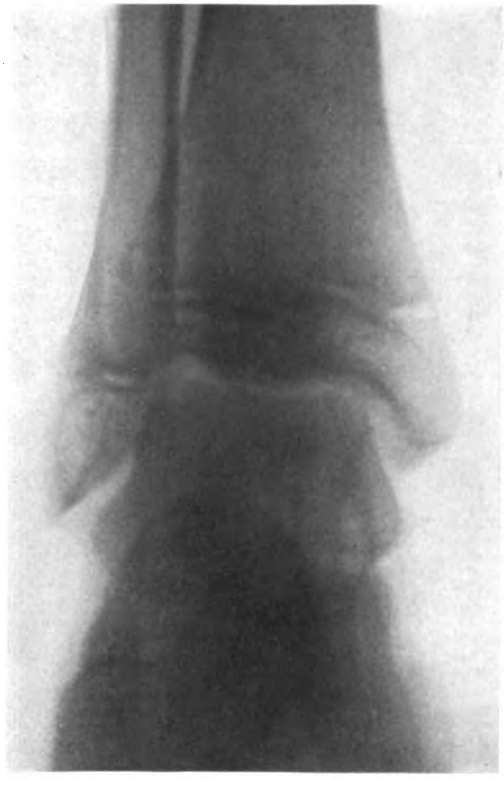
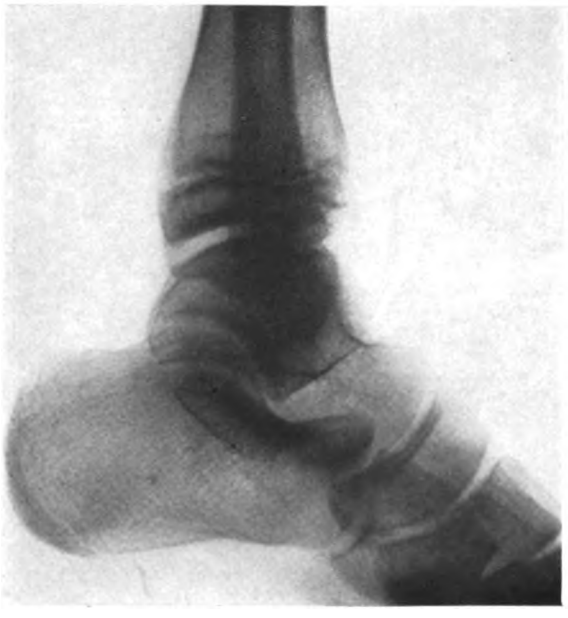


FIG. 239. FOURTEEN YEARS, TEN MONTHS.



FIGS. 240 AND 241. FIFTEEN YEARS.

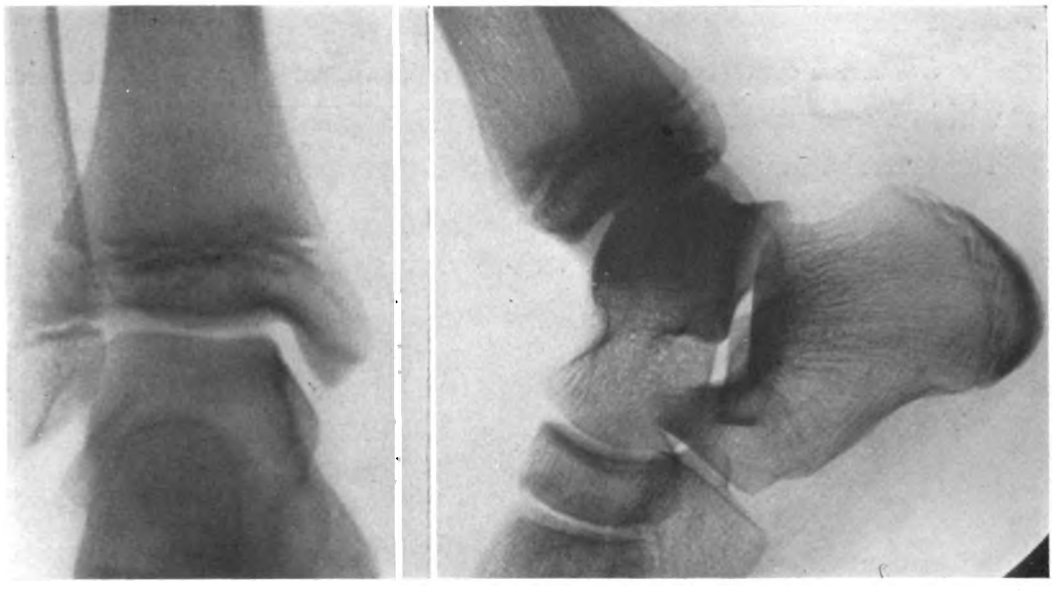
Digitized by Google

PLATE LIX

Fifteen Years (Fig. 242, 243). All the epiphyses are well developed but union between the respective epiphyses and diaphyses is incomplete.

Fifteen Years (Fig. 244). Complete ossification of all the epiphyses and union with the diaphyses.

Digitized by Google



FIGS. 242 AND 243. FIFTEEN YEARS.

FIG. 244. FIFTEEN YEARS.

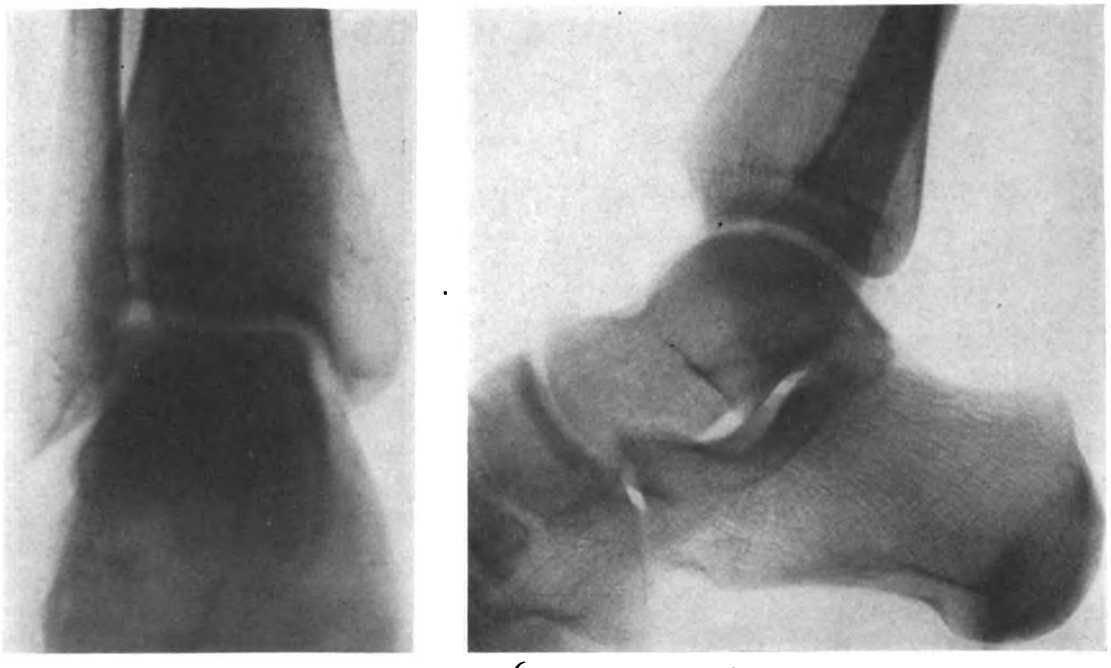
Digitized by Google

PLATE LX

Sixteen Years (Fig. 245). There is evidence of complete ossification within all the epiphyses and union of the respective epiphyses and shafts. The lateral view (Fig. 246) confirms this description.

Sixteen Years and Two Months (Fig. 247). Complete ossification of the epiphysis, but there is still a well-marked epiphyseal line separating the epiphysis and the diaphysis.

Digitized by Google



FIGS. 245 AND 246. SIXTEEN YEARS.

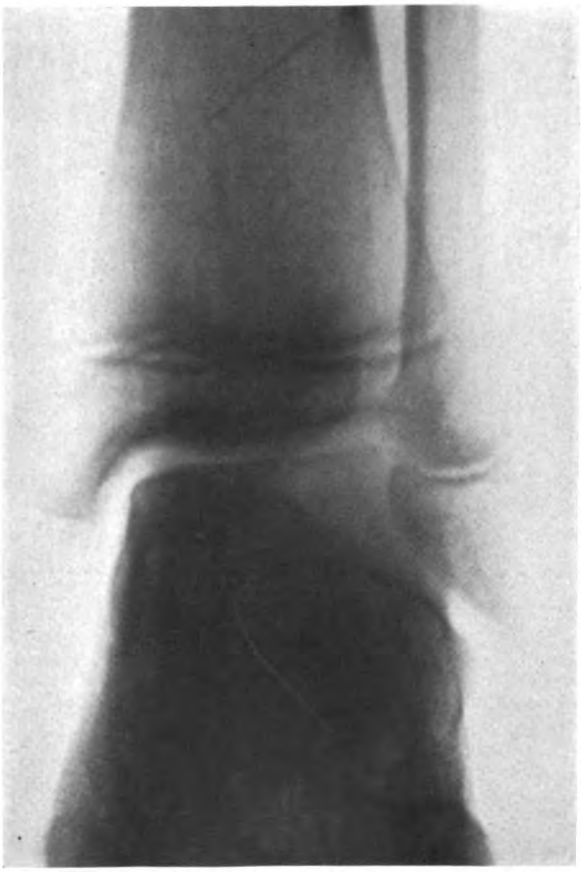


FIG. 247. SIXTEEN YEARS, TWO MONTHS.

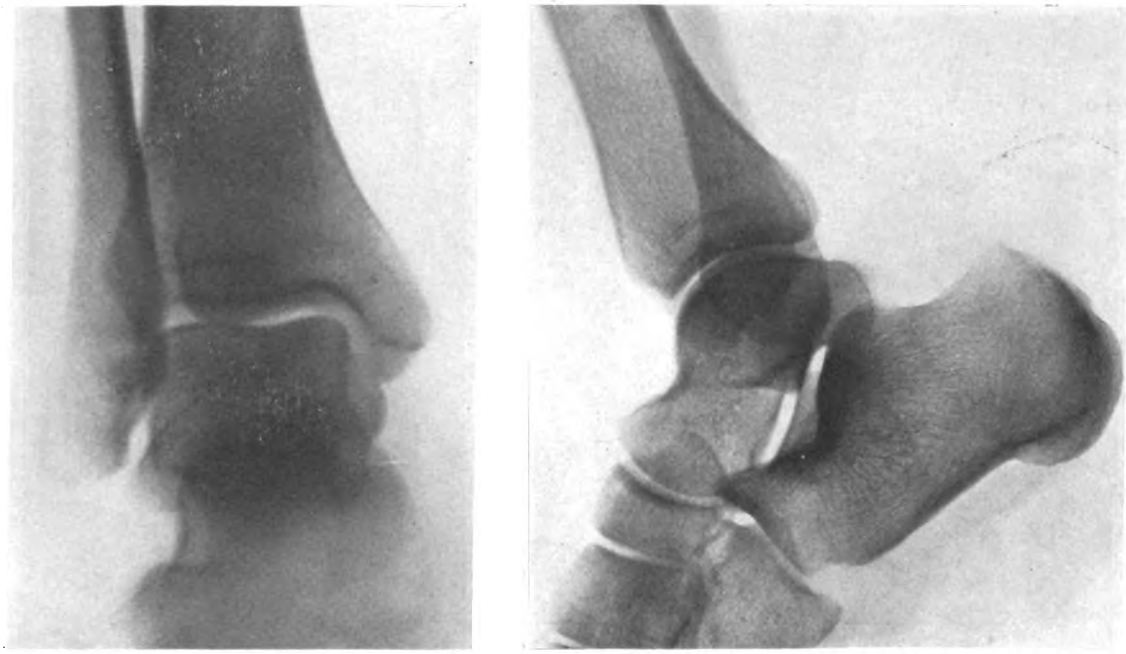
Digitized by Google

PLATE LXI

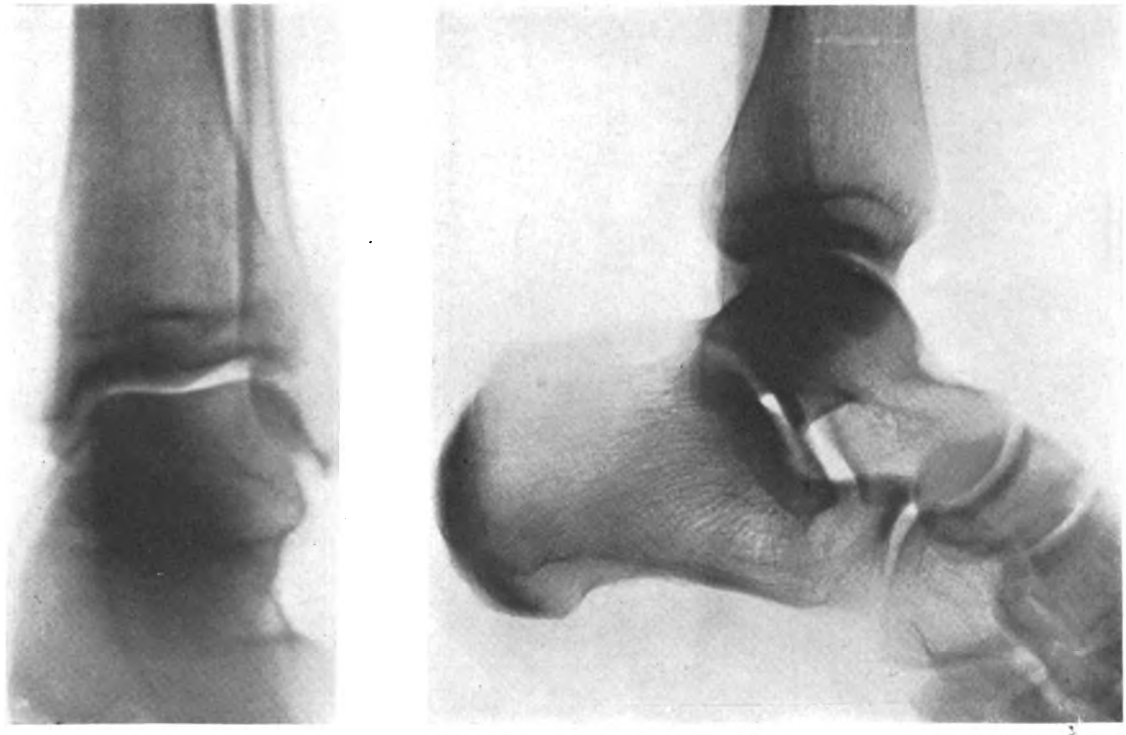
Eighteen Years (Figs. 248 and 249). Anteroposterior view. Complete ossification of both epiphyses and union of the respective epiphyses with the shaft. The lateral view presents the same appearance.

Nineteen Years (Figs. 250 and 251). Anteroposterior and lateral views show complete ossification of all the epiphyses and union and ossification of their respective epiphyseal lines.

Digitized by Google



FIGS. 248 AND 249. EIGHTEEN YEARS.



FIGS. 250 AND 251. NINETEEN YEARS.

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Date Due

OCT 12 '62			
Feb 14			

09.1.31.15.04

290412

QM 101
C67

Cohn, Isidore
Normal bones and joints.

QM
101
C67

290412

MEDICAL LIBRARY

Top stacks

Digitized by Google

The Ohio State University
3 2436 00013 9848
QM101C67 001
NORMAN BONES & JOINTS

THE OHIO STATE UNIVERSITY BOOK DEPOSITORY
D AISLE SECT SHLF SIDE POS ITEM C
8 02 09 06 8 13 007 9

Digitized by Google